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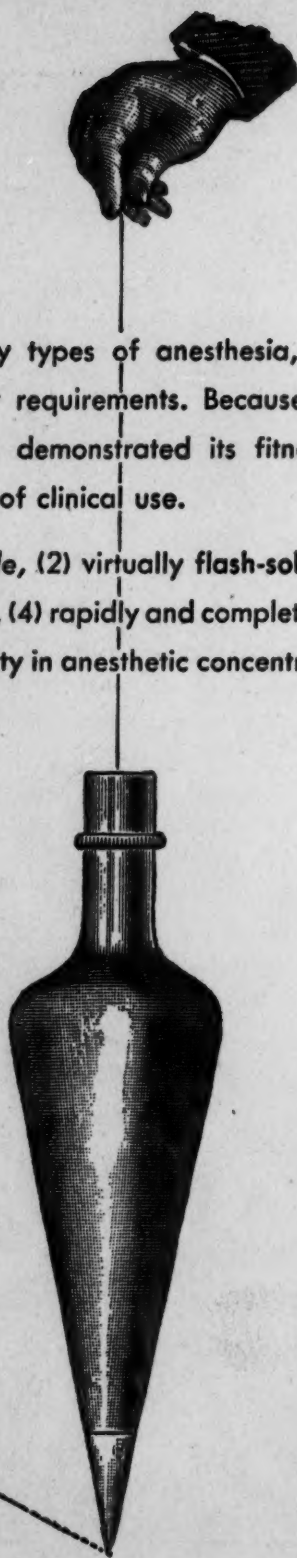
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EXARTICULATION OF THE LOWER EXTREMITIES FOR MALIGNANT TUMORS:

HIP JOINT DISARTICULATION (WITH AND WITHOUT DEEP ILIAC DISSECTION) AND SACRO-ILIAC DISARTICULATION (HEMIPELVECTOMY)

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PART III—SACRO-ILIAC DISARTICULATION (HEMIPELVECTOMY)

EXCLUSIVE OF THE present series, amputation through the sacro-iliac joint, not always complete, has been performed 132 times during the past 50 years. Seventy-five per cent of the operations were performed for neoplastic diseases. The infrequency with which this radical amputation has been employed may be ascribed both to the earlier high operative mortality rates and our meager knowledge concerning the clinical behavior of tumors. During the past quarter of a century, however, the operative mortality rate has been gradually lowered from 50 per cent to about 15 per cent. Despite this, the procedure is still resorted to with relative infrequency, something which cannot be entirely attributed to the mutilating features of the operation.

A surgical procedure, especially one of radical variety, becomes useful and increasingly employed only when its indications have been clearly established, the operative mortality rate is low and the end-results justify the deformity if there is any. The purpose of this section of the present report is to evaluate the usefulness and limitations of sacro-iliac disarticulation for malignant tumors and to *standardize* the surgical technic. This study is based on six cases of exarticulation of the lower limb through the sacro-iliac joint which were performed on the Mixed Tumor Service of the Memorial Hospital during 1944 and 1945. There were no operative deaths. The fact that the first operation of this kind was undertaken so late in the history of the Mixed Tumor Service may be explained by the many years which have been required to exploit more conservative therapeutic procedures, radiologic as well as surgical, for the treatment of malignant tumors of the soft somatic tissues before resorting to an extensive deforming operation, in addition to our present more comprehensive knowledge concerning the clinical behavior of tumors of these soft parts.

Definition.—The term sacro-iliac disarticulation or exarticulation of the

lower limb through the sacro-iliac joint is used to designate complete removal of the lower extremity, corresponding buttock and entire innominate bone in one stage. Other names which have been employed for this operation are interpelvi-abdominal amputation, hemipelvectomy, interiliosacropubic amputation, transiliac amputation, interinnomino-abdominal amputation, hindquarter operation and disarticulation of the innominate bone.

Historical.—The operation was first successfully performed by Girard^{6, 7} in 1895. The principles of the surgical procedure were laid down by the English surgeon, Hogarth Pringle⁸ in 1916. The technic to be described in this report is a modification of the original Pringle operation.

In 1916, Pringle reviewed the literature and reported four cases of his own. The literature was reviewed again by Judin,⁹ in 1926, Gordon-Taylor,^{10, 11} in 1935 and 1940, Leighton¹² and Morton,¹³ in 1942, and most recently by Sugarbaker.¹⁴ These authors reported one, eleven, three, four and six cases of their own, respectively. Approximately one-half of the previously published cases survived the operation. Thirty-five per cent of the tumor patients who survived the operation were reported to be clinically cured.

INDICATIONS

Sacro-iliac disarticulation is indicated for primary malignant osseous and periosteal tumors of the upper femur where the growth has extended to or through the hip joint and for similar neoplasms of the innominate bone (Figs. 19 and 20).^{*} Primary bulky malignant tumors of the soft somatic tissues of the upper thigh (involving the hip joint or extending through the obturator foramen), groin, buttock, pelvic parietes and iliac region are best treated by amputation through the sacro-iliac joint (Fig. 21).

This radical amputation occasionally has a definite place in the palliative therapy of cancer. Even in the presence of hopeless extension or distant metastasis, fungating ulcerated tumors of the soft somatic tissues of the upper thigh, groin and buttock may be removed in selected cases by sacro-iliac disarticulation and gratifying results may thus be obtained, provided the patient's general condition has not deteriorated too much (Fig. 22). Elimination of sepsis and pain, conversion of a foul-smelling, bedridden patient to comfort and partial activity can be accomplished in certain hopelessly advanced cases. When the entire lower limb and groin are the seat of an uncontrolled infected neoplastic process, like Kaposi's disease (Figs. 23 and 24), palliation may be provided by amputation through the sacro-iliac joint.

Massive osteochondromas of the innominate bone and massive plexiform neurofibromas involving the upper thigh, groin and hip joint or the buttock and pelvic parietes are best treated by exarticulation of the lower limb through the sacro-iliac joint, if the tumors contain atypical areas histologically and if

^{*} Figures 1-16 appeared in Parts I and II published in the June, 1946 issue of the ANNALS OF SURGERY.

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they cannot be adequately removed by wide local excision or some other type of conservative operation.

Possible involvement of the pelvic and abdominal viscera should always be investigated by careful physical, roentgenographic and endoscopic examinations. If necessary, preliminary celiotomy should be performed to ascertain

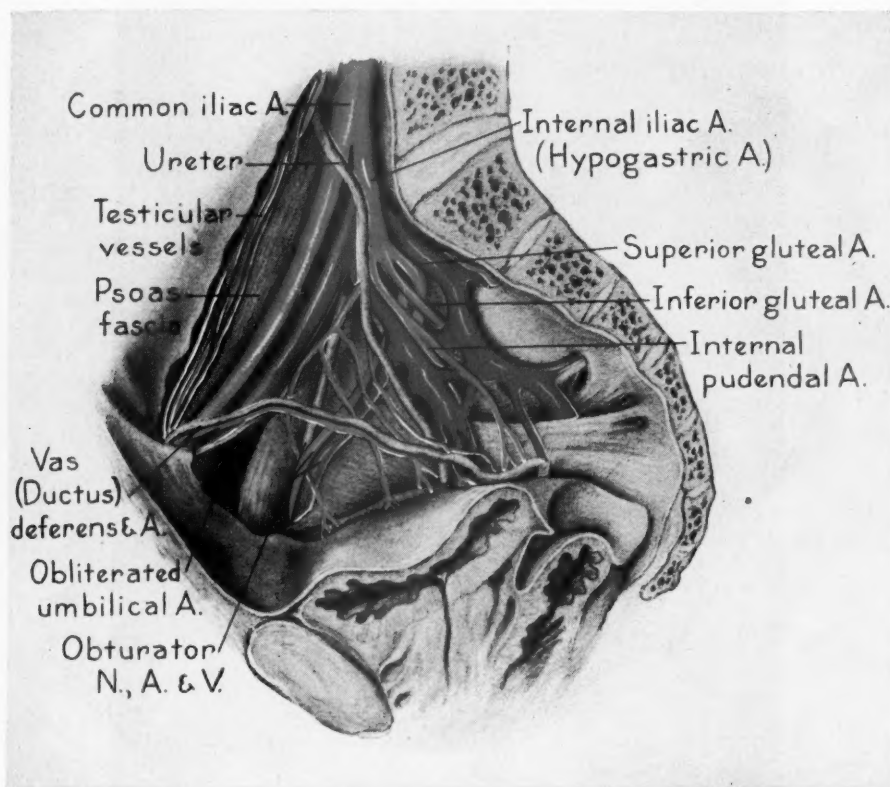


FIG. 17.—Sagittal view of pelvis and retroperitoneal space, showing the iliac vessels and their branches. (Redrawn from Grant's Atlas of Anatomy.)

the extent of the growth and possible peritoneal involvement. Wide extension of the neoplasm should not always deter the surgeon from performing the operation. Part of the sacrum was resected in one case and a testicle was removed in another in Gordon-Taylor's series.^{10, 11} In Case 6* of the present series, a considerable portion of scrotal skin was included in the dissection.

The operations which are here reported were performed for Kaposi's hemorrhagic sarcoma, myxoliposarcoma, chondrosarcoma, neurogenic sarcoma, periosteal fibrosarcoma and extra-osseous osteogenic sarcoma. One operation was performed for palliative purposes only (Case 1). It is mandatory that an anatomic diagnosis be established by aspiration or incisional biopsy before radical amputation or any other surgical or nonsurgical program

* Case numbers employed in Part III of this paper refer to our series, which are individually reported elsewhere in this section.

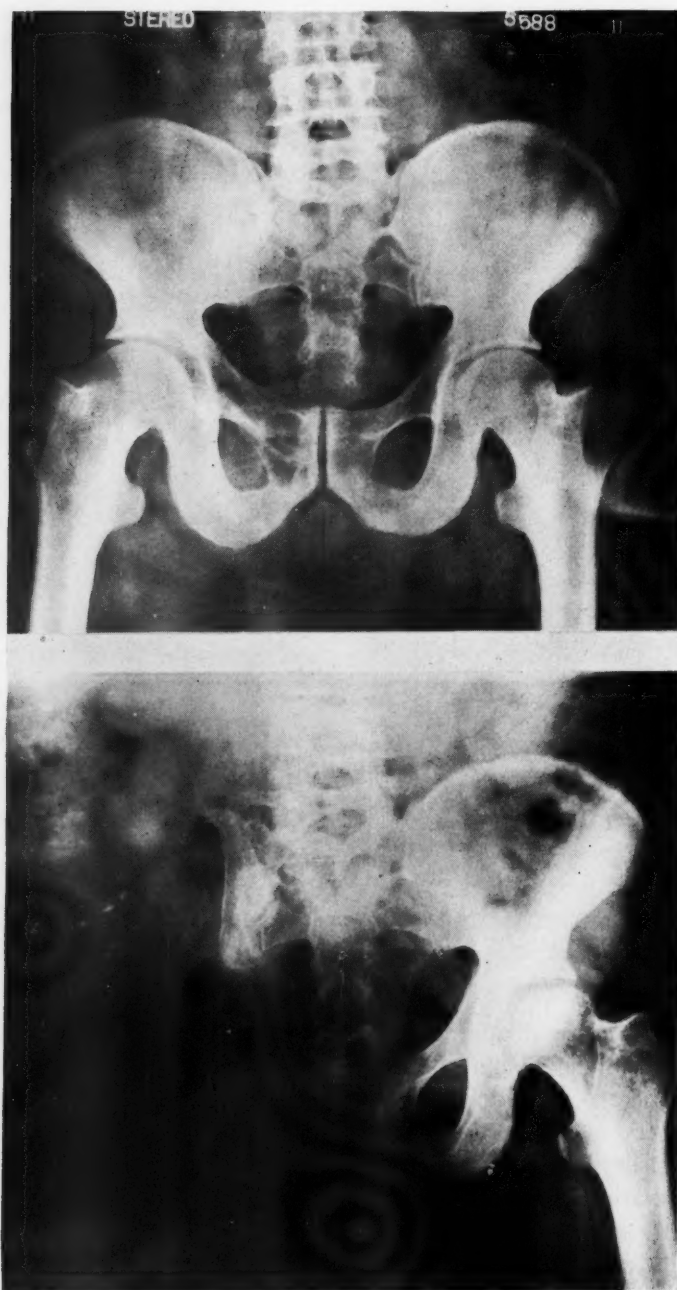


FIG. 18.—Roentgenogram of pelvis, showing chondrosarcoma of right pubis and ischium in Case 3. A favorable tumor for treatment by sacro-iliac disarticulation.

Below: Postoperative roentgenogram showing absence of affected innominate bone.

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for that matter is planned. Of the cases which were previously reported by other authors, one surgical specimen contained metastatic renal carcinoma¹⁴ and another metastatic thyroid carcinoma,¹³ whereas, in both of these cases the operations were carried out specifically for a primary malignant tumor.

PREOPERATIVE CONSIDERATIONS

The preoperative considerations and precautions which were discussed for hip joint disarticulation are also applicable for cases of sacro-iliac disarticula-

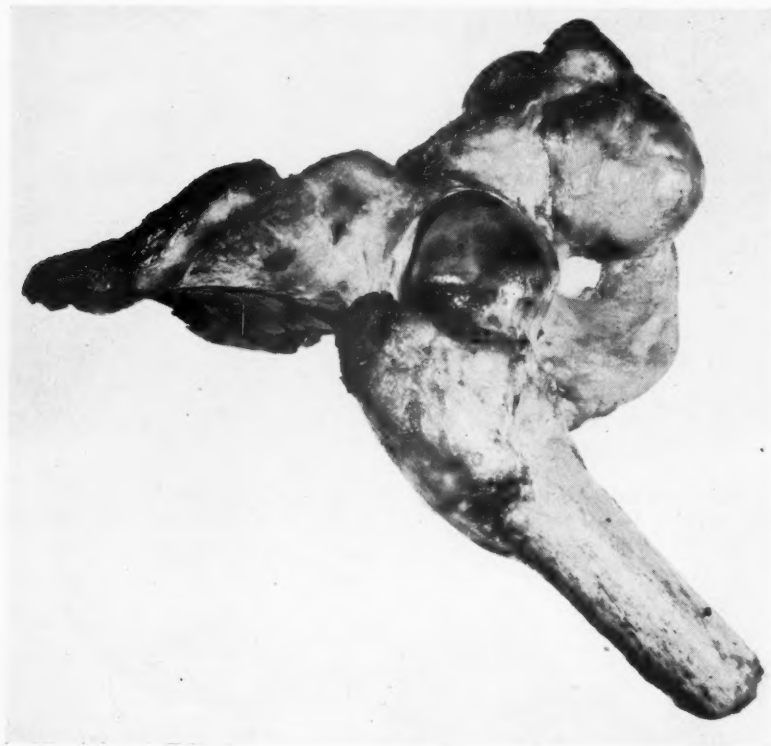


FIG. 19.—Surgical specimen in Case 3. Almost complete replacement of pubis and ischium by tumor.

tion. Douches and surgical cleansing of the vagina, daily antiseptic sprays and dressings, débridement for ulcerated, infected and necrotic tumors, blood transfusions for anemic and toxic patients, eradication of urinary tract infections and adequate correction of hypoproteinemia and other metabolic factors, if present, are essential features in preparing the patient for this radical operation. If the neoplasm is fungating extensively, much of the fungating portion may be excised with the cautery several days before amputation is performed (Case 6). In this way the operative field can be more thoroughly prepared. The application of an elastic bandage to the affected limb (except in cases of melanoma) and preoperative cleansing of the

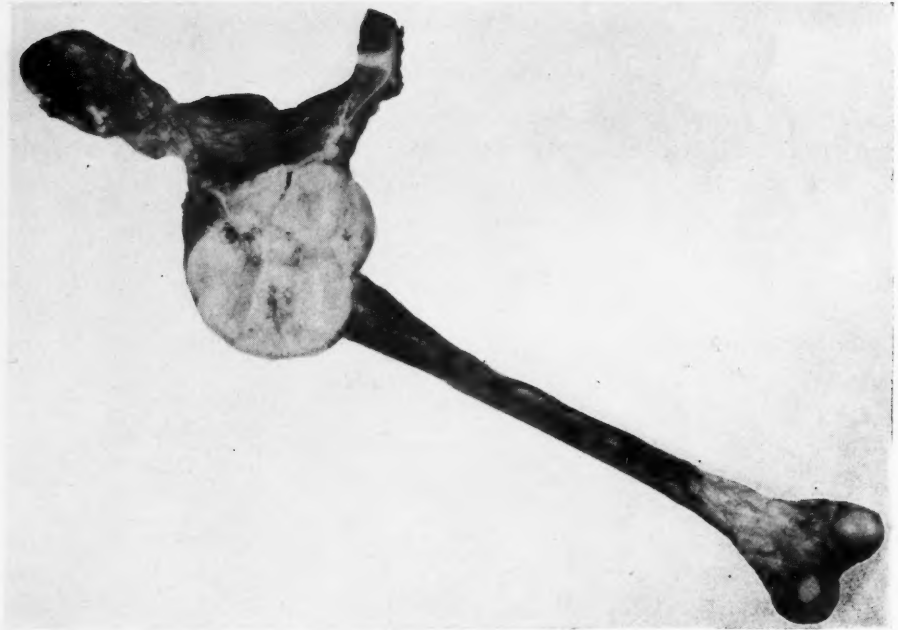


FIG. 20.—Surgical specimen in Case 5. Periosteal fibrosarcoma involving ischium, hip joint and greater trochanter. A malignant tumor so located can only be completely removed by sacro-iliac disarticulation.

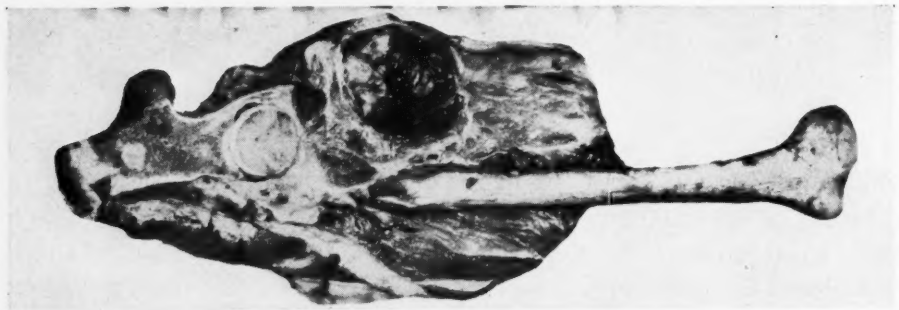


FIG. 21.—Surgical specimen in Case 6. Extra-osseous osteogenic sarcoma which presented as an ulcerated tumor in the groin and involved part of the scrotal skin. Treated by repeated cycles of roentgenotherapy elsewhere, with no regression, before admission to Memorial Hospital for sacro-iliac disarticulation. Note proximity of neoplasm to pubic bone and capsule of hip joint.

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bowel with colonic irrigations are highly desirable. A Foley urethral catheter is inserted into the bladder before the patient is taken to the operating room.

Inhalation anesthesia is the anesthetic of choice for reasons given in Part I of this report. A blood transfusion is begun as soon as the operation is started and an adequate amount of compatible blood should be on hand in the operating room.



FIG. 22.—Case 2: Extensive myxoliposarcoma of buttock. Neoplasm deeply infiltrated gluteal muscles and sacral foramina. Sacro-iliac disarticulation was performed to relieve intense intractable pain. Tumor could not be controlled with radiation therapy.

OPERATIVE TECHNIC

After the operative area has been cleansed and prepared, the anal opening is closed with a purse-string suture and, in the male, the scrotum is sutured to the opposite thigh. The skin of the entire field is again painted and the patient is draped.

An incision is made from a point just above the pubic tubercle, extending upward and outward, to a point just beyond the iliac crest. This incision corresponds to the curve of the inguinal ligament and the iliac crest. The posterior flap is outlined by carrying the lateral termination of the anterior incision downward coursing above the greater trochanter and along the infra-gluteal groove to the perineum. It is then joined with the medial end of the anterior incision at the superior border of the symphysis pubis (Fig. 25).

The anterior incision is deepened through subcutaneous tissues and fascia in its entirety. The rectus abdominis is divided at its insertion into the pubic bone. The inguinal ligament is severed at its lateral attachment to the anterior superior iliac spine and its medial attachment to the pubis. In this way the anterior abdominal wall is actually detached from the bony pelvis, forming the anterior flap. (Fig. 29). The spermatic cord is preserved and retracted.



FIG. 23.—Case 1: Kaposi's hemorrhagic sarcoma in a 16-year-old boy. Entire right lower limb and groin were ulcerated, infected and deeply invaded by tumor. Only the lesions on the left leg could be satisfactorily controlled with roentgenotherapy. Palliative amputation through the sacro-iliac joint restored a septic, foul-smelling, bedridden patient to comfort and partial activity.

The peritoneum is stripped off and the abdominal contents are pushed upward and medially; the urinary bladder is pushed downward and medially. The iliac fossa and its contents are thus exposed. Three structures—peritoneum, intestines and bladder—must be constantly retracted during the anterior dissection. The ureter must also be identified. The external iliac artery is doubly ligated and divided (Fig. 30). The external iliac vein is not ligated at this time to allow for a maximum return of blood from the limb. The pubic symphysis is exposed, skeletonized and easily divided with a Gigli saw or chisel (Fig. 31). The symphysis must be clearly identified, otherwise the corresponding or contralateral pubic arch will instead be transected. Considerable bleeding not infrequently follows separation of the symphysis pubis, due to cutting of vascular erectile tissue (ischiocavernosus). Hemorrhage is promptly controlled by packing.

The posterior skin flap is developed as far back as the sacrum (Fig. 32).

The anterior dissection is continued. The crest of the ilium is skeletonized, including severance of the attachment of the quadratus lumborum muscle. The external iliac vein is now doubly ligated and divided but the internal iliac vein is preserved. The iliopsoas muscle is then transected as high as possible. The iliacus, pyramiformis, gamelli and levator ani muscles are divided and the sacro-iliac joint is exposed (Fig. 33).

Disarticulation of this joint is performed during the anterior phase of the

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dissection, using a chisel. The bevel of the chisel and the direction of the instrument must be *away from the midline*. Injury to the hypogastric vein must especially be avoided at this time. The sacro-iliac synchondrosis is divided with relative ease. If difficulty is encountered, it is most probable that the ilium down through the sacrosciatic notch is being cut through rather than the synchondrosis. Troublesome bleeding which occasionally follows division of the sacro-iliac joint is controlled by packing and pressure.

The patient is turned on the unaffected side and the posterior dissection is carried out. The posterior attachments of the gluteal muscles are divided (Fig. 34). The limb is then sharply flexed and adducted. The specimen is now attached to the patient only by the major ligaments of the sacrum and the great nerve trunks. The ligaments are divided from below upward and the gluteal and obturator arteries are caught, cut and ligated. The specimen is removed (Fig. 35-A).

The large nerve trunks of the lumbar and sacral plexus are injected with alcohol and ligated. Absolute hemostasis is obtained. Sharp bony projections, if present, are eliminated. Redundant skin and muscle tags are trimmed and the wound is thoroughly irrigated with saline solution. The flaps are approximated with interrupted stitches after two cigarette drains have been placed in the defect and allowed to emerge through the ends of the wound (Fig. 35-B). The temporary scrotal and anal sutures are removed and a bulky pressure dressing is applied.

Anterior Dissection.—With this technic, all of the major phases of the operation are performed through an anterior approach except for division of the sacral ligaments, lumbar nerve trunks and gluteal and obturator arteries. The contents of the iliac fossa are easily exposed and the peritoneum, intestines and bladder can be retracted well out of the way, protecting them from possible injury. Both synchondroses may also be adequately exposed, cleared and divided under direct vision with little difficulty by approaching them anteriorly. Furthermore, it will not be necessary to turn the patient, occasionally in shock, too often in order to expose the necessary anatomic structures. The patient is turned only on three occasions—once for outlining the posterior incision, again, for development of the posterior flap, and a third time, when the posterior dissection or final phase of the amputation is performed.

Ligation of the Common Iliac Artery.—Amputation through the sacro-iliac joint may be performed in a relatively bloodless manner if the common rather than the external iliac artery is ligated. In this way there is no vigorous bleeding when the parietal branches of the hypogastric artery are cut and the amount of bleeding which follows division of the pubic and sacro-iliac synchondroses is amazingly small. Ligation of the common iliac artery, however, has its drawbacks and should not be done routinely. In Case 5 of the series here reported, the common iliac artery was ligated and the above observations with regard to hemostasis were made. At no time did the pulse or blood pressure change in any way. When the specimen was removed, the posterior flap appeared viable. On the fourth postoperative day there was some necrosis

along the suture line and two relatively small areas of necrosis appeared in the skin of the posterior flap. At this time, the wound began to drain large amounts of thick brown pus. On the seventh postoperative day the two eschars were excised and it was found that the middle third of the anterior half of the posterior flap was completely necrotic. Necrosis of the posterior flap following ligation of the common iliac artery for sacro-iliac disarticulation has also been observed by others.*

Ligation of the common iliac artery may be rarely indicated in poor risk patients where excessive bleeding, shock and a prolonged operation are to be avoided at all costs. Under such circumstances it might be preferable to risk possible necrosis of the posterior flap with its sequelae rather than an operative death. In such a case it would be advisable to develop an extremely thin posterior skin flap, making certain that it has been completely denuded of subcutaneous fat, for the blood supply which is destroyed by ligation of the common iliac artery essentially feeds into the subcutaneous fatty tissues and not into the overlying skin. In this way, the posterior flap becomes a full-thickness skin graft; if it is snugly and uniformly held against the underlying tissue bed by a judiciously applied pressure dressing, gangrene of the posterior flap and secondary infection might thus be avoided. The phenomenon of delayed or latent necrosis of the posterior flap which occurs after ligation of the common iliac artery for amputation through the sacro-iliac joint is actually secondary involvement of the skin by a gangrenous process which originates in the subcutaneous fat soon after the parietal branches of the hypogastric artery can no longer maintain an adequate circulation. It is only after spread of the necrotic process to the skin itself, which apparently takes a few days, that the necrosis can be seen externally, and by that time the wound is extensively infected.

Critical Period of the Operation.—The critical period of the operation is during partition of the sacro-iliac synchondrosis at which time shock occasionally occurs. Since the posterior dissection with subsequent division of the gluteal and obturator arteries immediately follows as the next step in the operation, it is essential that the blood pressure be maintained within reasonably normal limits before the posterior dissection is begun because it is during this last phase of the procedure that further appreciable hemorrhage might be encountered. Accordingly, we routinely start a second blood transfusion in the contralateral foot as a precautionary measure just prior to disarticulation of the sacro-iliac joint, so that the patient is not in shock at the time the specimen is removed.

Skin Grafting.—In the event that a considerable portion of the anterior or posterior abdominal walls must be included in the amputation because of involvement by tumor or radiation injury, the skin flaps might not be adequate

* A seventh hemiplevectomy has just been performed, with no postoperative complications. In this instance the common iliac artery was ligated early in the course of the operation. The wound healed *per primam*, with no evidence of ischemia and no infection. The patient was a 39-year-old man who had an enormous myxoliposarcoma of low-grade malignancy involving the left upper thigh anteriorly and extending superiorly to the groin and over the anterior superior iliac spine.

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for primary wound closure. Under such circumstances sufficient skin may be readily removed *from the amputated specimen* with the dermatome to cover the defect.

POSTOPERATIVE COMPLICATIONS

Aside from the distressing pains of phantom limb, a satisfactory postoperative course may be expected provided the proper prophylactic measures to prevent complications specific for cases of sacro-iliac disarticulation are instituted.

Abdominal Distention.—This is practically a constant and occasionally disturbing postsurgical complication. The etiology is obscure. Retraction and manipulation of the peritoneal contents for approximately three hours during the operation probably is not responsible for this complication. Division of the large nerve trunks of the lumbar and sacral plexus might conceivably depress the celiac and superior and inferior mesenteric sympathetic plexuses and, thus, account for the ileus. If a Levine tube is placed in the stomach as soon as the patient has fully reacted from the anesthetic and constant Wangenstein suction is continued for 48 to 72 hours, serious abdominal distention can be avoided. During this period fluid and electrolyte imbalance must be corrected and hypoproteinemia, a not uncommon complication, combatted by administration of large amounts of plasma.

Paresis of the Urinary Bladder.—Inability to void, due to paresis of the bladder, occurs often but is only temporary, lasting four to seven days. A Foley urethral catheter should be placed in the bladder before the patient is taken to the operating room. Thus, the bladder is kept empty during the operation and is less likely to be injured. When the patient is returned to his bed, urinary tidal drainage is established and maintained for about one week. Not only is this method of catheter drainage beneficial to the atonic bladder but it also prevents soiling of the dressing during the first postoperative week. When the catheter is finally removed, patients void spontaneously. No instance of postsurgical urinary tract infections were encountered.

Wound Healing.—Continued and often profuse drainage for a period of about three weeks is almost a constant feature following sacro-iliac disarticulation. This may be attributed to necrosis of muscle tags, lymphorrhea and liquefaction of fat. Necrosis of skin flaps will occur if the blood supply is inadequate or if the tissues have been devitalized by roentgenotherapy. In Case 5 of this series the common iliac artery was ligated and the posterior flap underwent extensive latent necrosis. In Case 6, healing was unsatisfactory due to previous radiation therapy to the operative site, and pinch-grafts were required to cover the resultant defect. If the tumor has been previously heavily irradiated, every effort should be made to excise all of the radiated skin, otherwise delayed or nonhealing is inevitable.

Frank wound infections were commonly encountered despite exhaustive preoperative prophylactic measures, which were discussed elsewhere in this report, and adequate postoperative chemotherapy. The proximity of the oper-

ative area to the anus and genitals, the ulcerated, necrotic and extensively infected state of many of the neoplasms, postoperative anemia and hypoproteinemia, together with a frequent history of heavy irradiation to the tumor, were the factors which contributed to the high incidence of postsurgical wound infections. There were no instances of vesical, enteric or ureteral fistula or permanent sinus formation in our cases or in any of the previously reported cases where the operation was performed for neoplastic disease.

Osteomyelitis was encountered in one instance (Case 6). At this operation the contralateral pubic arch was divided, instead of the pubic symphysis, thus exposing cancellous bone. Since the tumor had been extensively infected and previously heavily irradiated, this complication was inevitable.

Anemia.—This is a characteristic postoperative manifestation following sacro-iliac disarticulation but does not consistently appear after hip joint, interscapulothoracic or any other type of amputation. Naturally, patients who require sacro-iliac disarticulation are not infrequently anemic because of sepsis, radiation therapy or malnutrition due to pain. In these cases the blood picture is brought to within reasonably normal limits by appropriate preoperative measures. Some of the patients may lose considerable blood during the operation. This loss, however, is adequately replaced by blood transfusions. In those cases where the blood loss is 500 cc., or less, anemia still appears during the immediate postsurgical period. In Case 5 of the present series the common iliac artery was ligated and the blood loss was negligible; this patient, too, developed an anemia. It also occurs when massive blood transfusions are not given during the operation and, therefore, cannot be attributed to excessive destruction of red cells in the spleen, with subsequent bone marrow depression. The anemia can neither be ascribed to blood loss during operation or to any specific systemic preoperative factors. It is not unlikely, therefore, that removal of an entire lower extremity and innominate bone deprives the hemopoietic system of sufficient active bone marrow, thus producing anemia. This normocytic normochromic anemia is noted during the first few postoperative days and persists for about three weeks. It does not respond to blood transfusions, liver or iron therapy. An increase of reticulocytes in the peripheral blood and of nucleated red cells in the sternal marrow were also noted postoperatively, indicative of compensatory marrow hyperplasia.

Function of Anal Sphincter.—Fecal incontinence or other disturbances of sphincteric control do not occur following sacro-iliac disarticulation despite complete division of the levator ani muscle on the affected side. This may be attributed to the cross-insertion of these muscles so that preservation of the sphincter and an intact contralateral levator ani muscle are wholly adequate for satisfactory sphincter control.

Hernia.—The abdominal contents are merely supported by skin, subcutaneous tissue, fascia and peritoneum, yet there has been no instance of herniation. There is no need, therefore, for preserving the gluteus maximus muscle since it does not materially make for a better stump. No device for supporting the abdominal wall is necessary, although one has been introduced.¹⁵

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Prosthesis.—A prosthesis has never been devised for these cases. The patients learn to sit on the opposite ischial tuberosity. They manage to use crutches satisfactorily after about three weeks of practice. Despite the mutilating features of this radical amputation the psychologic adjustment parallels that following ordinary amputation, except that loss of libido occurs rather frequently.

CASE REPORTS

Case 1.—*Sacro-iliac Disarticulation for Kaposi's Hemorrhagic Sarcoma of the Lower Extremity:*

A. G., a white male, age 16, was first seen at the Memorial Hospital, September 29, 1944, for Kaposi's hemorrhagic sarcoma involving the lower limbs. Bluish nodules in the skin of the right leg were noted in 1938. In 1941, the patient was subjected to a bilateral saphenous vein ligation for varicosities. Shortly after, the tumors on both lower limbs were treated with roentgen ray. On admission, the patient was profoundly anemic, bedridden and suffering from sepsis. There were literally thousands of tumor nodules which involved both lower extremities (Fig. 23). The lesions on the left leg had been satisfactorily controlled with previous radiation therapy. The tissues of the right lower limb were edematous and infiltrated by tumor up to and including the femoral trigone. The odor was extremely foul. Radiographic studies of the chest and bony pelvis revealed no evidence of metastasis.

The infection could not be controlled by local care or chemotherapy, and the pain was intense. Radical amputation for palliation was, therefore, decided upon. Hip joint disarticulation could not be undertaken because considerable tumor would be left behind. Accordingly, a right sacro-iliac disarticulation was performed on November 8, 1944. Since the skin of the entire limb had been replaced by infected fungating tumor reaching to the level of the greater trochanter, a considerable portion of skin had to be sacrificed. This was accomplished by placing the anterior racquet incision at a point midway between the umbilicus and anterior superior iliac spine. Otherwise the usual technic for amputation through the sacro-iliac joint was carried out. The patient received two liters of blood during the operation and one and one-half liters during the first five postoperative days.

The wound healed satisfactorily except for moderate serous drainage for a period of three weeks. The only complications of note were abdominal distention and anemia. At no time was there any fecal incontinence. After four days of continued catheter drainage the patient was able to void spontaneously. He was discharged on the 25th postoperative day. Follow-up examinations have revealed several recurrent nodules in the skin of the right lower anterior abdominal wall which responded satisfactorily to low-voltage roentgenotherapy.

Pathology.—Almost the total area of the skin surface of the exarticulated hindquarter was involved by multiple and conglomerate, infected, foul-smelling, grayish-brown nodules. There was considerable thickening of the skin. The lesions were scattered from the toes to the upper thigh. The entire extremity was greatly swollen. On sectioning, the subcutaneous tissues and muscle were found to be deeply invaded by tumor. Numer-



FIG. 24. — Postoperative photograph in Case 1.

ous large masses were encountered in the inguinal and iliac regions. The line of amputation lay well above the uppermost recognizable lesion. Microscopic study revealed the usual structure of Kaposi's hemorrhagic sarcoma. The nodules in the inguinal and iliac regions proved to be discrete tumors adjacent to but not involving the lymph nodes.

Comment.—This procedure was purely palliative for an hopelessly advanced infected tumor which had completely disabled the patient. The operation succeeded in removing an offensive tumor-ridden limb so that the patient regained a reasonable measure of health and is again ambulatory (Fig. 24).

Case 2.—Sacro-iliac Disarticulation for Myxoliposarcoma of the Buttock.

M. M., a 57-year-old white female, was first seen at the Memorial Hospital, July 31, 1944, for a tumor of the right buttock of 15 years' duration. The previous history was essentially normal. The neoplasm had been excised 11 and nine years ago, respectively; two subsequent recurrences were treated with roentgenotherapy. For one month prior to admission the patient had severe intractable pain in the right buttock and pelvis. This buttock was the seat of a reddened, indurated, infiltrating tumor, measuring about 6 cm. in greatest diameter (Fig. 22). The central portion of the mass was necrotic and ulcerated. Several discrete nodules were palpable in the right iliac region. Radiographic studies of the chest, spine and bony pelvis revealed no evidence of metastasis. A biopsy was reported myxoliposarcoma.

After two weeks of preparation, which included local cleansing, penicillin therapy and blood transfusions, a right sacro-iliac disarticulation was performed in the usual manner. During the operation it was noted that the tumor extended deep to the underlying muscles, replacing two-thirds of the buttock. It was densely adherent to the adjacent ilium and also extended through several sacral foramina. The patient received two liters of blood during the procedure.

Convalescence was complicated by the development of a phlebothrombosis in the opposite leg which was treated by femoral vein ligation. At no time was there any fecal incontinence. After four days of continuous catheter drainage the patient was able to void spontaneously. Abdominal distention was a prominent feature during the first postsurgical week and was treated by an indwelling gastric tube and Wangenstein suction. An additional liter of blood was administered during the first postoperative week for anemia, which persisted despite this treatment. The patient was discharged on the 23rd postoperative day with some slight serous discharge from the wound.

On May 23, 1945 severe pain developed in the upper part of the stump. Examination revealed a tender mass in the right iliac area. Roentgenogram of the chest showed no evidence of lung metastasis. The patient was readmitted to the hospital for a course of high-voltage roentgenotherapy, after which there was marked regression of the mass and complete amelioration of symptoms. Several days after the completion of roentgenotherapy, flaccid paralysis of the remaining lower extremity developed together with loss of urinary bladder control. Neurologic examination disclosed evidence of cord block at D 7 to D 9. Radiographic studies of the spine revealed no evidence of bony involvement. Lumbar puncture yielded clear straw-colored fluid under an initial pressure of 95 mm. of water; the final pressure was 20 mm. The spinal fluid protein determination was 1,110 mg. per 100 cc. of spinal fluid. Urinary tidal drainage was established and the involved thoracic spinal segment was outlined for roentgenotherapy.

On June 27, 1945 the patient developed chills and fever up to 105° F. She continued very septic, and expired, July 2, 1945, approximately one year after amputation. Permission for an autopsy was not obtained.

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Pathology.—The right buttock contained a deep, dirty, foul-smelling, ulcerated tumor, measuring 8 cm. in greatest diameter. The tumor was soft, gelatinous and partly cystic. It extended through the gluteus maximus muscle and soft tissues adjacent to the greater sciatic notch. There was no actual infiltration of bone. It was reasonably certain from gross examination that the neoplasm had not been completely excised. Microscopic study revealed the usual histologic features of myxoliposarcoma.

Comment.—This is another instance of amputation through the sacro-iliac joint for palliative purposes only. A cure could not be anticipated in this case because the tumor had extended through the sacral foramina, with the expectancy that the spinal cord would eventually become involved. The operation succeeded in removing a necrotic, infected, foul-smelling hindquarter which was the source of intense intractable pain and which made the patient offensive to others. The tumor could not have been controlled by roentgenotherapy.

Case No. 3.—*Sacro-iliac Disarticulation for Chondrosarcoma of Pubis and Ischium.*

J. M., a 60-year-old white male, was first seen at the Memorial Hospital, January 18, 1945 for a mass in the right groin of six months' duration. The tumor produced considerable pain especially on walking. There had been no apparent increase in its size since it was first noted. Examination revealed a definite mass in the right parapubic area. Radiographic studies showed evidence of a multicystic, expansile, osteolytic process involving the right pubis and ischium (Fig. 18). It did not appear to extend into the ilium or acetabulum. Roentgenograms of the chest and remaining skeleton revealed no evidence of this disease process. Aspiration biopsy yielded no characteristic tissue.

An exploratory operation was carried out January 19, 1945. Tissue was submitted to the Pathologic Laboratory for immediate examination and a diagnosis of chondrosarcoma was made. A right sacro-iliac disarticulation was then performed in the usual manner. Because of the size of the tumor, it was necessary to expose the posterior urethra and prostate gland. The patient received one liter of blood during the procedure and one liter during the first four postoperative days.

There was no fecal incontinence. The patient was able to void spontaneously after seven days of tidal bladder drainage. During the first postsurgical week the convalescence was complicated by marked ileus, which was treated with continuous Wangenstein gastric suction and daily colonic irrigations. The wound healed satisfactorily and ceased to drain during the third postoperative week. A normal blood count was also obtained at this time. The patient was discharged on the 28th postoperative day.

Pathology.—The specimen consisted of an entire lower extremity, buttock and corresponding innominate bone. Examination of the major vessels revealed no evidence of intravascular tumor extension. There were no grossly involved lymph nodes. After the soft tissues and muscles were dissected from the innominate bone, a large mass was seen to occupy the pubic bone (Fig. 19). The tumor was covered by a relatively thick capsule which apparently was the fascial covering of the neighboring muscles. The neoplasm was composed of grayish, cartilaginous-like tissue intermingled with opaque grayish areas. It extended through the obturator foramen. On section of the innominate bone, the growth was seen to involve most of its pubic portion. It also extended for a short distance into the proximal ilium and distal portion of the ischium. The articular capsule of the acetabulum in the region of the pubis was also involved. The cortex of the bone was intact everywhere except for the ramus of the pubis. The neoplasm entirely replaced the marrow of the involved portion of bone. Abundant new periosteal bone formation was seen at the junction of pubis and proximal ilium. In its over-all dimensions the tumor measured 8 x 8 x 7 cm. Microscopic study revealed the usual structure of chondrosarcoma.

Comment.—Sacro-iliac disarticulation was necessary in order to excise a bulky malignant tumor which almost replaced half of the bony pelvis. The growth was surgically accessible. The prognosis following amputation through the sacro-iliac joint is best in this type of case.

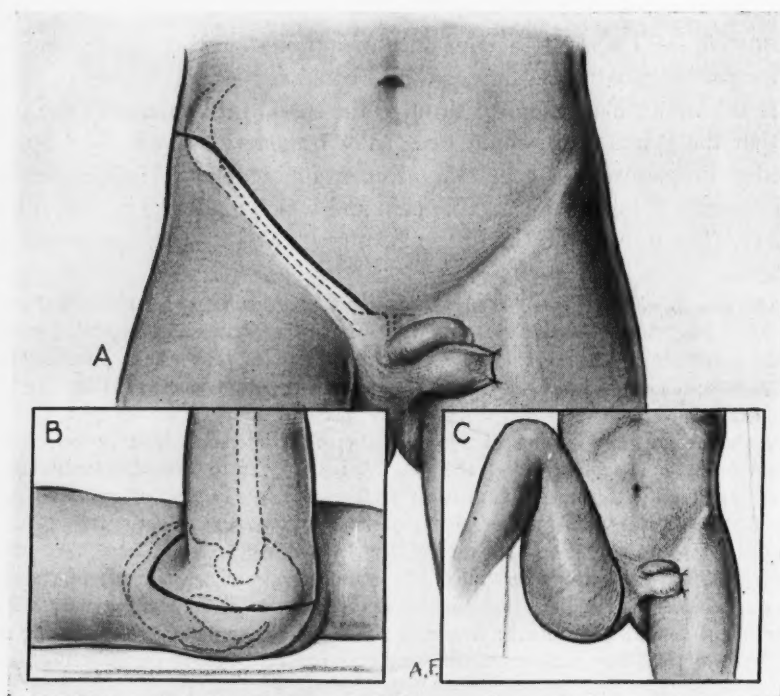


FIG. 25.—Incision for sacro-iliac disarticulation.

(A) The anterior incision extends from the pubic tubercle to beyond the iliac crest, paralleling the inguinal ligament.

(B) The posterior flap is outlined by carrying the lateral termination of the anterior incision downward, coursing above the greater trochanter and along the infragluteal fold to the perineum.

(C) The anterior and posterior incisions are then joined at the superior border of the symphysis pubis.

Case No. 4.—*Sacro-iliac Disarticulation for Neurogenic Sarcoma of the Thigh and Pelvic Parietes.*

L. R., a 15-year-old white female, was first seen at the Memorial Hospital, November 19, 1936, for von Recklinghausen's neurofibromatosis. No familial history of this disease could be elicited. In 1935, the patient sustained an injury to the left buttock, which was followed by considerable pain and swelling. The pain subsided after two weeks but the swelling persisted and slowly increased in size.

The child was undersized. Diffuse circumoral pigmentation was present. Numerous café-au-lait spots were distributed over the trunk and limbs but no discrete superficial neurofibromas were palpable. Situated on the posterior aspect of the upper left thigh just beneath the gluteal fold was an oblong tumor, measuring 13 x 10 x 10 cm. (Fig. 26). The mass was movable and not adherent to bone or skin. Roentgenograms of chest and left

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femur showed no evidence of metastasis or bone involvement. The liver was not palpable. Aspiration biopsy yielded no characteristic tissue for diagnosis. A clinical diagnosis of neurogenic sarcoma of the left sciatic nerve was made.



FIG. 26.—Case 4: Von Recklinghausen's neurofibromatosis. Plexiform neurofibroma on posterior aspect of left thigh (not associated with sciatic nerve). Excised in 1936. Note *café-au-lait* spots, which are frequently present in this disease.



FIG. 27.—Case 4: Seven years later. Fully-developed neurogenic sarcoma originating in sciatic nerve. Tumor extended through obturator foramen to involve pelvic parietes. This extension was first determined by exploratory operation through the thigh and buttock. A favorable case for amputation through the sacro-iliac joint.



FIG. 28. — Postoperative photograph in Case 4.

On December 9, 1936, wide local excision of the mass was done. An encapsulated, edematous, partly cystic tumor, measuring 8 cm. in longest diameter, was found beneath the short head of the biceps femoris muscle. The neoplasm was attached to a medium-sized branch of the sciatic nerve and extended down to but did not involve the periosteum of the femur. It also extended along the sciatic nerve downward to the popliteal space and upward to the obturator foramen. Numerous nodular, firm, encapsulated masses were present all along the sciatic nerve—characteristic of this disease. The large neoplasm was easily excised but no attempt was made to enucleate the myriads of neuromas which involved all median and large nerve trunks. The sciatic nerve was left intact. Microscopic examination of the excised tumor revealed the typical structure of plexiform neurofibroma, lacking any of the true features of malignant transformation.

The patient was examined at periodic intervals for the next seven years and on February 26, 1945 a mass, measuring 10 x 6 cm., was noted beneath the upper end of the scar (Fig. 27). Aspiration biopsy was done and a diagnosis of neurogenic sarcoma was established. An attempt at wide local excision was carried out on March 30, 1945. The neoplasm actually replaced a greater portion of the main sciatic nerve and perforated the obturator foramen to involve the pelvic parietes. Removal of the tumor through this approach was impossible. The wound was closed. Sacro-iliac disarticulation was advised but consent was not granted until three months later.

On June 15, 1945, a left sacro-iliac disarticulation was performed in the usual manner. During the operation it was noted that all major nerve trunks contained numerous neuromas. The patient received two liters of blood during the procedure. Although studies for estimation of blood loss were not carried out, it was considered less than average in this case.

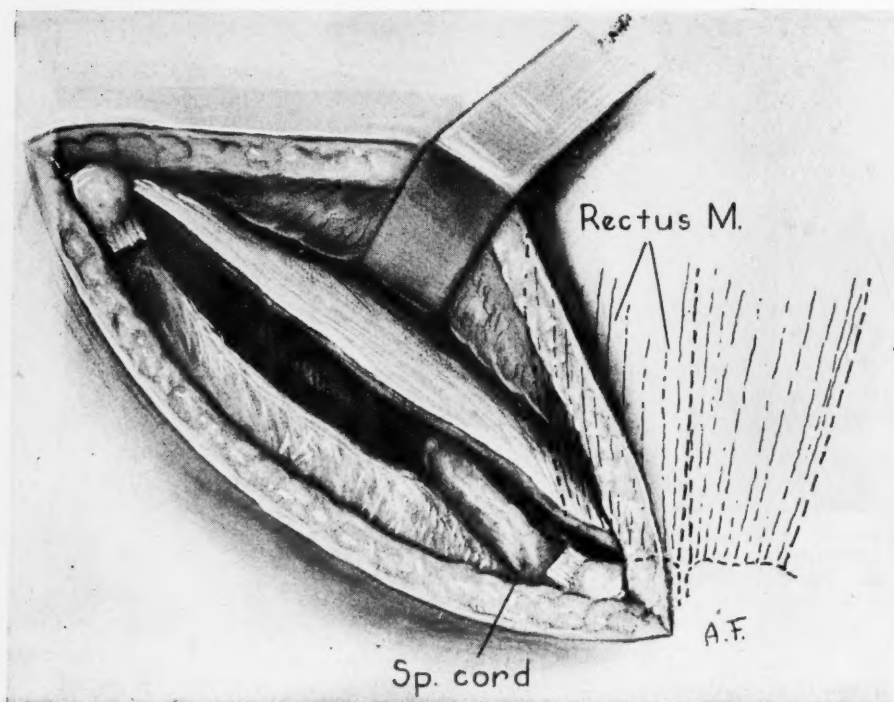


FIG. 29.—The public insertion of the rectus abdominis muscle has been cut. The medial and lateral attachments of the inguinal ligament have been severed. Thus, the anterior abdominal wall is detached from the bony pelvis. Spermatic cord is preserved.

During the first two postoperative weeks the patient's anemia was profound, and did not respond to repeated blood transfusions, liver or iron therapy. Aside from this, the convalescence was uneventful. There was no bowel disturbance or abdominal distention. An indwelling gastric tube was inserted after the patient had fully reacted from the anesthetic; it was attached to Wangenstein suction and left for four days. This was a significant factor in preventing ileus. Tidal bladder drainage was continued for seven days after which the patient had normal bladder control. The wound healed *per primam*, and serous drainage ceased after the 18th postoperative day. The patient was discharged on the 21st postoperative day (Fig. 28).

Pathology.—The sciatic nerve was replaced by a bulky, hard, irregular, grayish tumor, which measured 20 x 7 cm. It invaded the following muscles: obturators, gamelli, biceps femoris, semimembranosus, semitendinosus and quadratus femoris. The obturator foramen had been perforated and the pelvic parietes were involved. Throughout the entire extent of the sciatic nerve and its tibial and perineal branches were myriads of neurofibromas. Even the small subcutaneous and muscular branches contained numerous fusi-

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form nodules. Microscopic examination revealed the main tumor mass to be neurogenic sarcoma. Many of the nodules which studded the major and minor nerve trunks were also studied histologically and proved to be plexiform neurofibromas.

Comment.—This case illustrates malignant transformation of a plexiform neurofibroma of the von Recklinghausen type. These patients should be care-

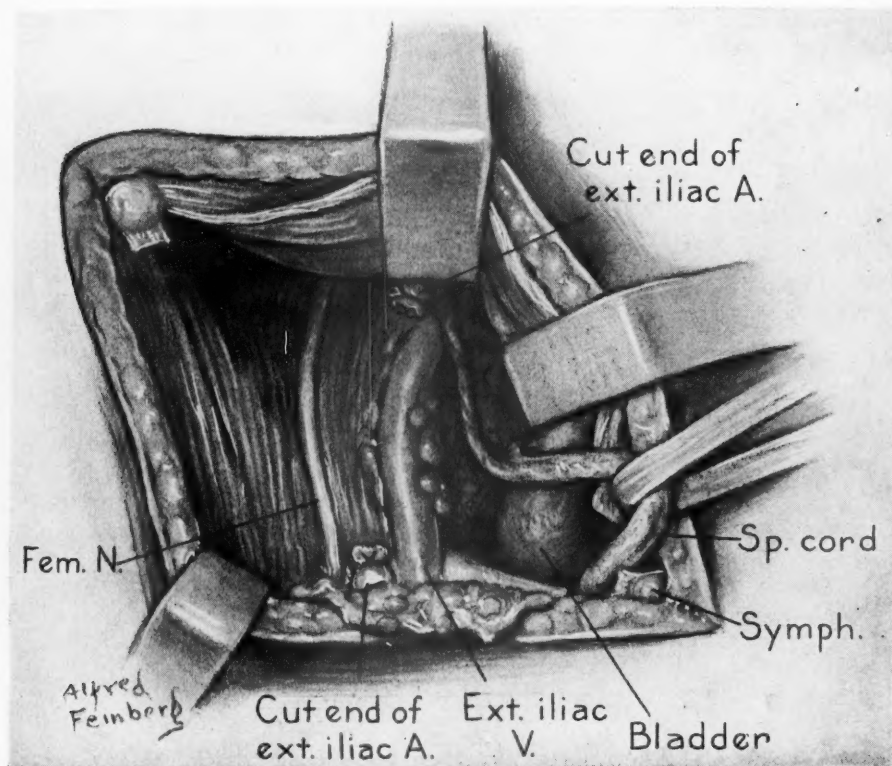


FIG. 30.—The retroperitoneal space has been exposed by pushing the peritoneum, its contents and the urinary bladder upward and medially. The external iliac artery has been ligated and divided. The external iliac vein is not ligated at this time to allow for a maximum return of blood from the limb.

fully examined at frequent periodic intervals so that neurogenic sarcoma may be detected relatively early, before extensive mutilating surgery becomes necessary. The tumor had perforated the obturator foramen. An exploratory operation can always be performed to ascertain such extension. Obviously it was not possible to remove this tumor in its entirety without resorting to amputation through the sacro-iliac joint. This patient might develop other neurogenic sarcomas in the neuromatous nodules of the lumbar plexus.

Case 5.—*Sacro-iliac Disarticulation for Periosteal Fibrosarcoma of Ischium.*

D. F., a 45-year-old housewife, was referred to the Memorial Hospital, August 8,

1945, for a tumor of the buttock. She had complained of pain in the lower back, left thigh and groin for nine months. Examination revealed a bulky, stony hard mass involving most of the left buttock. It measured about 15 cm. in diameter. The overlying skin was unchanged and unattached, but the growth appeared to be adherent to the underlying bone. No nodes were palpable in the groin or retroperitoneal space. There was considerable spasm of the muscles of the thigh and leg. Blood count showed a moderate anemia. Roentgenologic studies revealed destruction in the subcapital portion of the neck of the left femur and the presence of a large soft-part mass associated with the bony erosion. Roentgenograms of the lungs were negative for metastasis. Aspiration biopsy was performed and a diagnosis of unclassified spindle cell sarcoma was made.

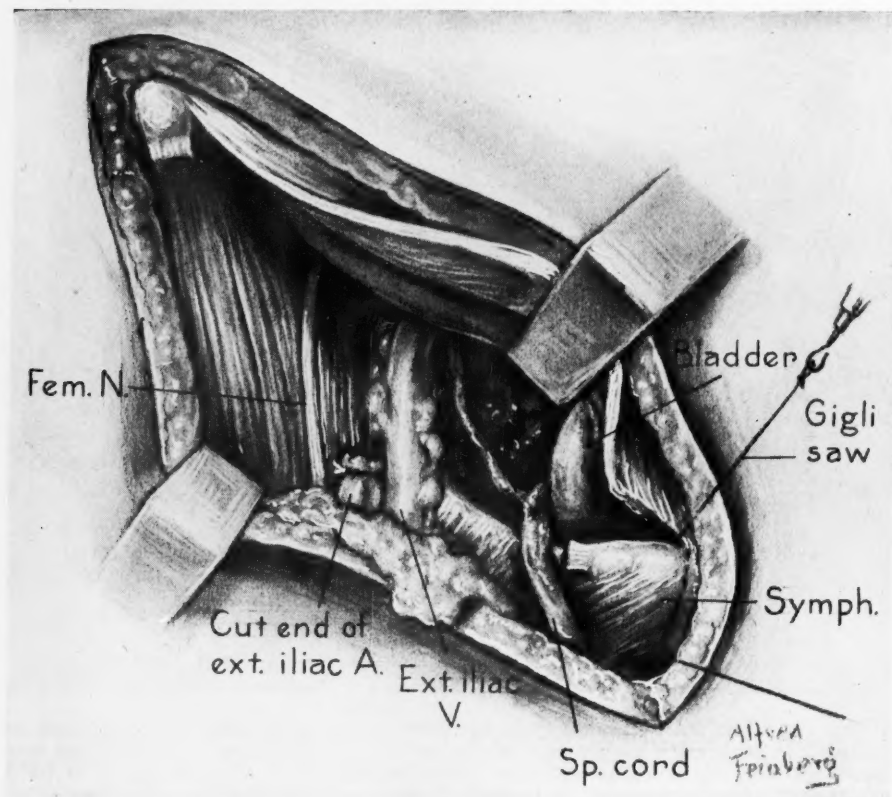


FIG. 31.—The symphysis pubis is skeletonized and then divided with a Gigli saw. The bladder must be retracted well out of the way during this phase of the operation. The symphysis must be clearly identified, otherwise the corresponding or contralateral pubic arch will, instead, be transected. Note that the external iliac vein is still intact.

Left sacro-iliac disarticulation was carried out, August 29, 1945, in the usual manner except that the common iliac rather than the external iliac artery was deliberately ligated. No significant bleeding was encountered anywhere. The usual hemorrhage which follows partition of the pubic symphysis and sacro-iliac synchondrosis did not occur. Bleeding from the parietal branches of the hypogastric artery was sluggish. At the close of the operation the posterior skin flap appeared viable. One thousand cubic centimeters of blood was administered during the operation. The blood pressure was continually stable and at no time did the pulse rate change.

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A Levine tube was placed in the stomach as soon as the patient had reacted from the anesthetic and continuous suction was applied. No significant abdominal distention occurred and gastric intubation was discontinued on the fourth postoperative day. Tidal bladder drainage was maintained for one week, after which the patient was able to void spontaneously; the residual urine varied from 75 to 100 cc. for several days after discontinuance of bladder drainage. There was no disturbance of the anal sphincter. The post-surgical course was complicated by anemia and severe hypoproteinemia.

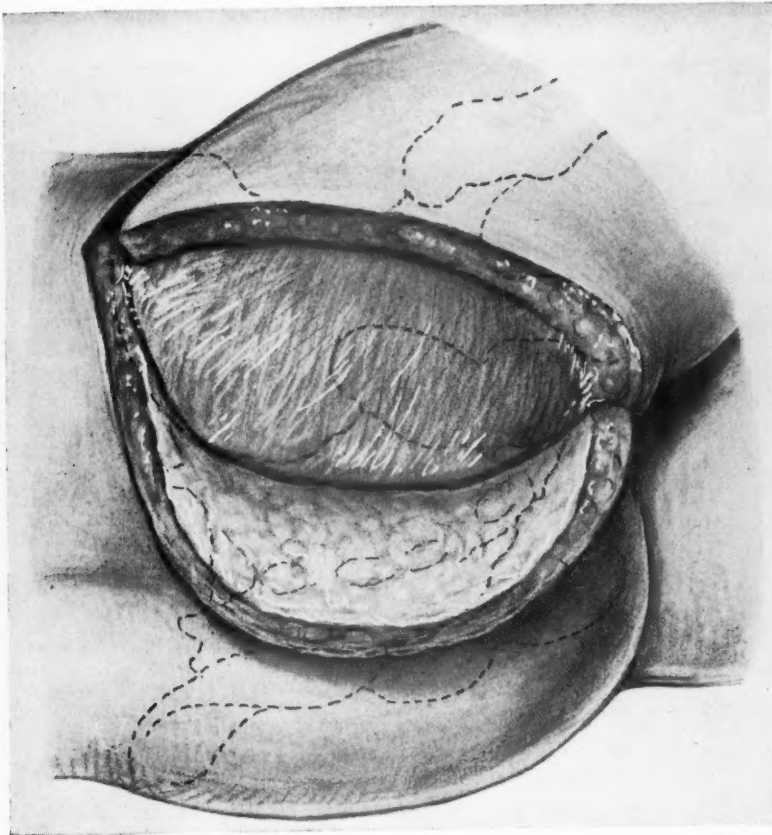


FIG. 32.—The posterior skin flap is developed as far back as the sacrum.

On the fourth postoperative day two areas of necrosis were noted on the posterior flap adjacent to the suture line and the wound drained large amounts of thick brown pus (*B. coli*). The eschars were excised three days later, and at this time the anterior half of the posterior skin flap was found to be completely necrotic. A débridement was performed and the underlying fascia was not found to be necrotic. The resultant defect measured 12 x 10 cm. The skin over the sacrum appeared unchanged at all times. The wound was cleansed daily, using power sprays and dakinized packs. The infection slowly subsided and granulation tissue appeared. On October 2, 1945, secondary wound closure was performed under intravenous (pentothal sodium) anesthesia. The flaps were approximated without tension, using interrupted sutures of fine steel wire. The wound continued to drain for several weeks but finally healed. About one week after the secondary closure, the wound flora was predominantly *B. pyocyaneus*, and this infection responded satisfactorily to

irrigations of one per cent acetic acid. The patient was discharged on the 61st post-operative day.

Pathology.—Situated in the upper posterior thigh and extending into the buttock was a well-delineated, but unencapsulated, roughly oval tumor, measuring 11 cm. in longest diameter (Fig. 20). The neoplasm was deeply embedded in the soft parts and was covered posteriorly by the gluteus maximus and hamstring muscles. The lower pole of the growth rested on the quadriceps femoris muscle. Nowhere did the tumor infiltrate the muscle planes. Its external surface was glistening and slightly lobulated and on cut-section was found to be composed of yellowish-white homogenous tissue containing areas of hemor-

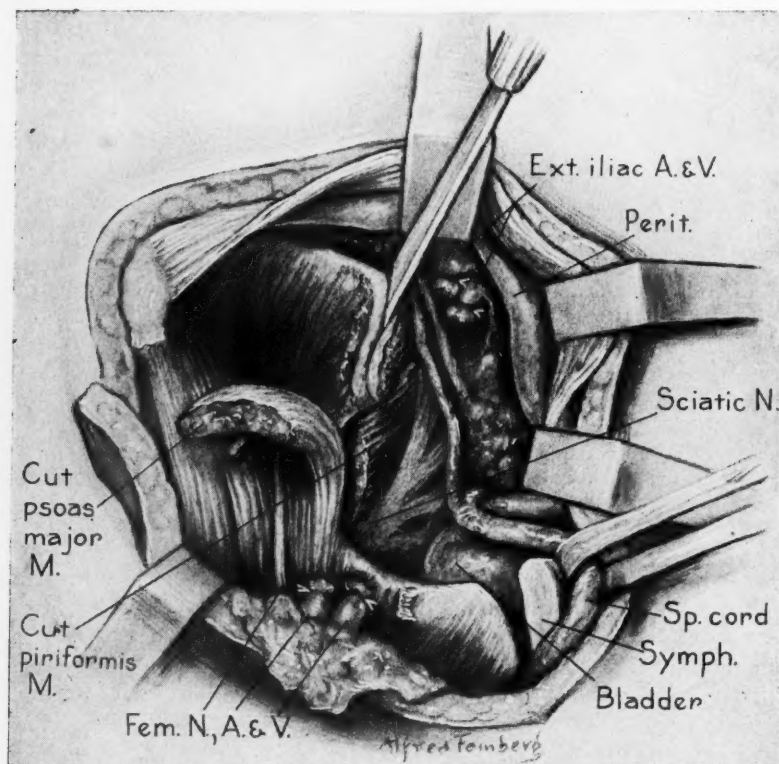


FIG. 33.—Anterior dissection continued. The ilium has been completely skeletonized and the external iliac vein has finally been ligated and divided. The sacro-iliac joint is exposed by transecting and reflecting all the overlying muscles. Disarticulation of this joint is best performed during the anterior dissection-phase of the operation. Bevel of chisel and direction of the instrument must be away from the midline.

rhage, necrosis and fibrosis. It was firmly attached superiorly to the soft tissues adjacent to the rami of the pubis and ischium. Anteriorly, in the infrapubic area, the growth was distinctly lobulated and infiltrative, extending to the posterior inferior iliac spine. The capsule of the hip joint and its adjacent soft tissues were involved. The inferior portion of the acetabulum and the ligamentum teres were destroyed by tumor. The obturator foramen had not been perforated. The head and neck of the femur and most of the ischium were also invaded. Microscopic diagnosis was periosteal fibrosarcoma.

COMMENT.—Even though this tumor involved the upper thigh, buttock,

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hip joint and a considerable portion of the innominate bone, it was possible to circumscribe and excise it by performing an amputation through the sacro-iliac joint. Although ligation of the common iliac artery assured a relatively bloodless operation, latent necrosis of the posterior skin flap occurred, resulting in extensive and serious wound infection. The ensuing defect was finally obliterated by successful secondary wound closure. Ligation of the common iliac artery was responsible in this case for considerable morbidity and a protracted convalescence.

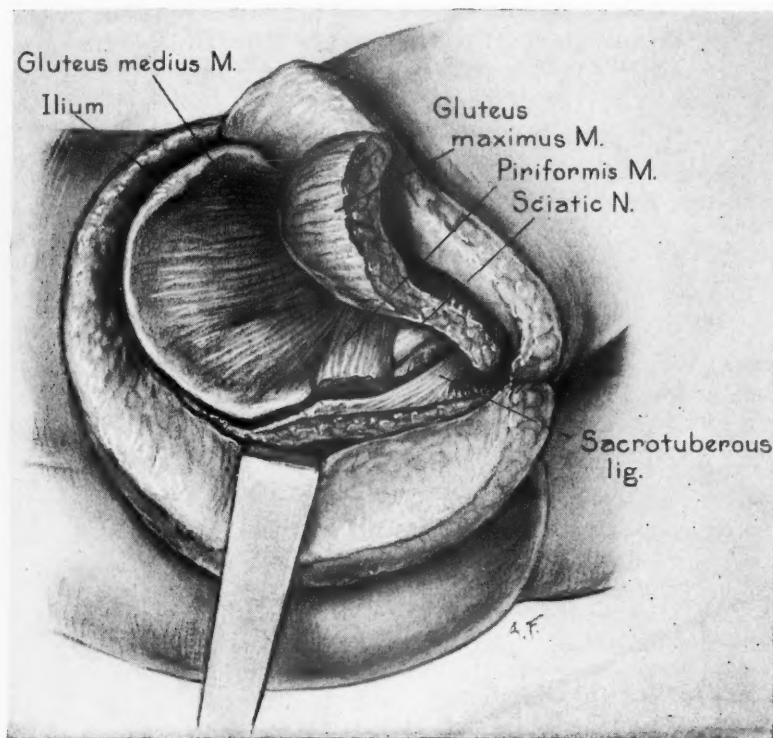


FIG. 34.—Posterior dissection. After partition of the sacro-iliac joint, the patient is turned on the unaffected side and the innominate bone is further mobilized by transecting the sacral muscular attachments. The specimen is now attached to the patient only by the major ligaments of the sacrum and the great nerve trunks of the lumbar and sacral plexus.

If the patient is a very poor risk, where unavoidable hemorrhage and shock might contribute toward an operative death, it is preferable to ligate the common rather than the external iliac artery even though necrosis of the posterior flap is inevitable. Under such circumstances the posterior skin flap should be made very thin, denuding it of all subcutaneous fat. A judiciously applied dressing will maintain this large thin skin flap (analogous to a skin graft) uniformly and snugly against the underlying tissues. In this way extensive

necrosis, with subsequent infection and loss of the posterior flap, might be averted.

Case 6.—*Sacro-iliac Disarticulation for Extra-osseous Osteogenic Sarcoma of Groin and Thigh.*

E. M., a 57-year-old white male, was first seen at the Memorial Hospital, July 25, 1945, for a tumor of the thigh of one year's duration. Two weeks after the growth was first noted, it was excised and a diagnosis of liposarcoma was made. Accordingly, a course of high-voltage roentgenotherapy was administered. Two recurrences appeared within the ensuing six months, and each of these was treated with roentgenotherapy. After the third recurrence the patient was referred to the Memorial Hospital.

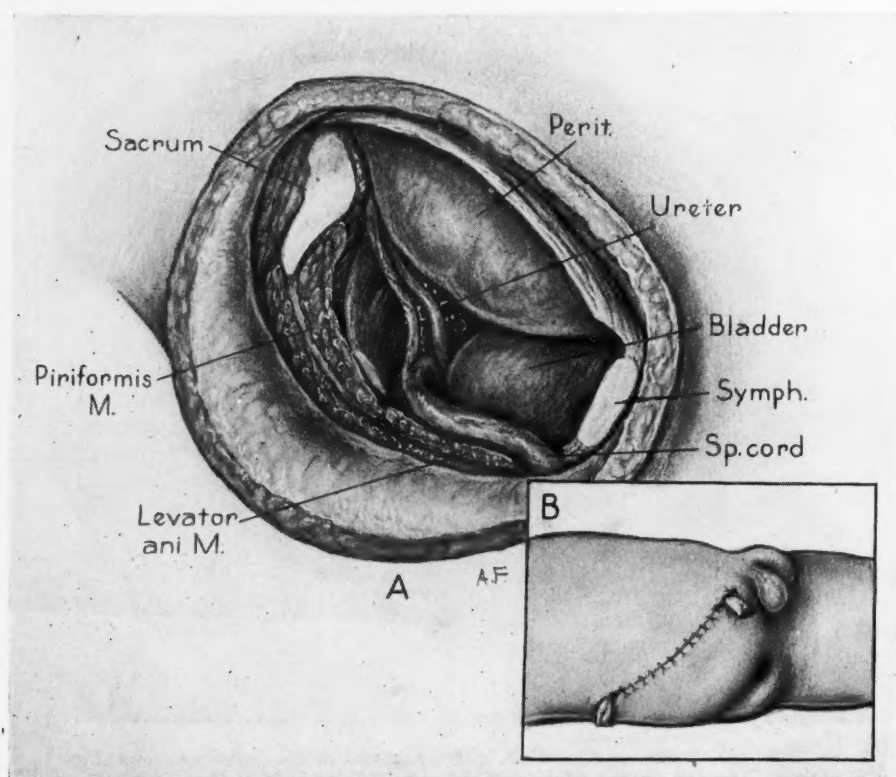


FIG. 35.—(A) Amputation through sacro-iliac joint completed.
(B) Wound closure.

On admission, he complained of intense pain in the entire right lower limb, groin, hip joint and perineum. There was much difficulty in moving the affected extremity. The patient had been bedridden for two months, and was consuming considerable quantities of narcotic drugs daily. Examination revealed evidence of past and recent heavy irradiation to the skin of the upper thigh and groin. Situated in the groin and upper inner thigh was an ulcerated, infected, deeply infiltrating tumor. The crater measured 3 cm. in diameter, and its edges consisted of fungating, largely necrotic, friable neoplastic tissue. The inguinal ligament in its distal half was thickened, as was the adjacent portion of the scrotum. Drainage from the ulcerated growth was profuse and foul-smelling. On rectal examination, extensive induration was noted in the right pararectal tissues, suggesting the pres-

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ence of tumor. Roentgenologic examination of the bony pelvis, femur and lungs revealed no evidence of involvement. Biopsy of the growth was made and reported extra-osseous osteogenic sarcoma.

Proctoscopic examination was negative. On cystoscopy, several pink, soft, discrete, noninfiltrating masses were seen near the left ureteral orifice and a similar lesion was noted between the ureteral orifices, suggesting a primary bladder tumor rather than direct extension or metastases from the tumor in the groin. Microscopic examination of several biopsy specimens from the bladder revealed epidermoid carcinoma, Grade 1. It was believed that the bladder, urethra, prostate gland and the rectum were not involved by osteogenic sarcoma.

On August 5, 1945, limited cautery excision of the fungating portions of the tumor in the skin was performed in order that daily cleansing of the ulcerated growth could be performed more efficiently. On August 23, 1945, the infection was well-controlled, so that the tumors in the bladder could be safely fulgurated through the cystoscope.

One week later right sacro-iliac disarticulation was performed in the usual manner. Extensive skin damage, due to previous radiation therapy, and marked thickening of the adjacent portion of the scrotum necessitated the sacrifice of some skin on the anterior abdominal wall, one-third of the adjacent scrotum and a small amount of contiguous perineal skin. Many of the anatomic landmarks were either indistinct or entirely obliterated. The spermatic cord, bladder, urethra, prostate gland and rectum were not involved by tumor. There was no intraperitoneal or retroperitoneal extension. Hemorrhage was considerable due to recent radiation therapy and the extensively infected state of the tumor and surrounding tissues. The patient was given 1,500 cc. of blood during the operation, which he tolerated without mishap.

The standard postoperative precautions were taken (indwelling gastric tube attached to suction, tidal bladder drainage, blood and plasma transfusions, correction of water and electrolyte imbalance, vitamin therapy, chemotherapy). No bowel or urinary disturbances occurred, and abdominal distention was only moderate. The postsurgical course was complicated by anemia, hypoproteinemia, wound infection, poor wound-healing and finally osteomyelitis of the remaining pubis. The edges of the medial third of the wound, adjacent scrotum and perineal skin remained reddened and indurated and showed no tendency to heal. A profuse discharge was present (*Proteus vulgaris* predominating).

On the 32nd postoperative day a pocket of pus was discovered in the distal end of the wound and was appropriately drained. Ten days later a swelling was noted in the suprapubic area and the overlying skin was reddened. The patient offered no complaints, there was no temperature elevation, but marked local tenderness was present. Roentgenologic studies revealed evidence of osteomyelitis of the pubic ramus. At operation, a large parapubic and paravesical abscess was evacuated. Curettage of the affected bone was carried out. Subsequent treatment of the wound consisted of dakinization, followed later by activated zinc peroxide packings. Resolution of the infection occurred slowly, and the patient was discharged on the 68th postoperative day, with a 3-cm. sinus in the parapubic area.

Pathology.—Situated in the upper medial thigh and groin was an ulcerated deeply infiltrating mass. Cut-section revealed it to be roughly oval in shape, sharply circumscribed but unencapsulated. It measured 7 cm. in longest diameter. The growth extended downward to within 2.5 cm. of the shaft of the femur. Superiorly, it reached to within one centimeter of the capsule of the hip joint and 3 cm. below the ramus of the pubis. At no point did it appear to be associated with any bony structure (Fig. 21). The neoplasm did not involve the obturator foramen. It was largely composed of gelatinous, grayish friable tissue showing extensive necrosis. Firm gritty areas were also present. The central portion of the tumor was necrotic with cavity formation. No osseous or cartilaginous components could be recognized macroscopically. Final histologic diagnosis was extra-osseous osteogenic sarcoma.

COMMENT.—The presence of a second primary malignant tumor (epidermoid carcinoma of the urinary bladder) was discovered during the preoperative investigative period and did not contraindicate a surgical program designed to remove a bulky, recurrent, deeply infiltrating, malignant tumor of the thigh and groin. Operability in this case was borderline due to possible involvement of the rectum. It was reasonably certain, after continued study of the problem, that the rectum was not involved by tumor. If further evidence to decide rectal or pararectal extension was necessary, exploratory celiotomy could have been performed.

The necrotic, ulcerated and infected state of the tumor necessitated a lengthy period of presurgical preparation, including preliminary cautery excision of the fungating portions of the tumor, in an effort to reduce the septic condition of the tissues and to prepare the operative field. Even though amputation included skin of the anterior abdominal wall, scrotum and perineum, it was ostensibly inadequate, for poor wound-healing resulted from the presence of heavily irradiated skin contiguous to the suture line. Wider skin excision, even if followed by the application of an immediate split-thickness graft, would have undoubtedly lessened the morbidity and shortened the convalescence in this instance.

Osteomyelitis of the remaining pubic bone was due to the presence of exposed cancellous bone in a preëxisting soft-tissue infection. Division of the symphysis pubis rather than the contralateral pubic arch would most likely have prevented this unfortunate complication. Obliteration of anatomic landmarks, due to infection, edema and previous heavy irradiation, made exposure and visualization of these structures difficult.

PROGNOSIS AND END-RESULTS

The prognosis following sacro-iliac disarticulation for malignant tumors will depend on the anatomic type and extent of the tumor, the number of recurrences prior to the operation and the presence of distant metastasis. The soft-part neoplasms which carry the best prognosis following this operation are neurogenic sarcoma and nonmetastasizing low-grade spindle cell sarcoma of the fascial-tendon type. Of the bone tumors, chondrosarcoma offers the most favorable prognosis.

In the present series of six sacro-iliac disarticulations, two were performed for palliation only. Five patients are alive and well, with no evidence of recurrence or distant metastasis at the present writing and one patient (palliation case) died of recurrent disease one year after operation. All of our cases, of course, are relatively recent. With regard to previously reported cases in the literature, one-third of the patients who submitted to this operation because of malignant neoplastic disease were reported to be clinically cured. The follow-up period in many of these cases, however, was most inadequate. The number of carefully followed cases is too few as yet on which to base an accurate and final evaluation of the operation. The accumulated evidence indicates that sacro-iliac disarticulation will prove to be a valuable surgical procedure for

the treatment of extensive cancers of the lower extremity, bony pelvis and pelvic parietes.

SUMMARY AND CONCLUSIONS

Twenty-five cases of hip joint disarticulation and six of sacro-iliac disarticulation for malignant tumors are reported and analyzed. The principle of exarticulation of an extremity, with excision of the involved regional lymph nodes, for selected cases of malignant melanoma and clinically similar tumors is introduced and illustrated by five cases of hip joint disarticulation combined with deep iliac dissection. Standardized technics for all three operations are described and illustrated.

The postoperative complications specific for cases of amputation through the sacro-iliac joint and their prevention are discussed. These extensive surgical procedures need not be hazardous. There were no operative deaths in this series.

Radical amputations (disarticulations) serve a definite and distinctly useful rôle in the treatment of selected cases of cancer of the lower extremity, buttock, groin, innominate bone and pelvic parietes.

ABSORBABLE GAUZE IN BONE SURGERY*

EXPERIMENTAL STUDIES SUGGESTING CLINICAL APPLICATION IN
RECONSTRUCTION OF JOINTS

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THE PROPERTIES of oxidized cellulose or cellulosic acid, its absorbability when introduced in the various tissues, and its usefulness when used as an hemostatic packing in wounds of different viscera have been described and discussed in preceding papers. In one of these papers it was mentioned by one of us (Frantz,¹¹ Surg. Clin. N.A.) that when oxidized cellulose was used in clean experimental fractures there was evidence of delay in bone repair.

We are now reporting our experimental study of the reparative processes of bone in the presence of different types of absorbable sponges—oxidized cellulose (gauze or cotton), human fibrin foam with thrombin and absorbable gelatin ("Gelfoam") with thrombin—used for hemostatic purpose.

Dogs were used for all of the following experiments. Intravenous nembutal anesthesia was employed and the usual aseptic technic observed.

In a first group of experiments in which seven dogs were used, the upper third of the radius was exposed by a muscle-splitting incision through the extensor muscles. After denuding the bone of periosteum, two or three drill holes were made down to the marrow cavity. With the aid of a small chisel these holes were then united so as to obtain a cavity which measured 3 to 4 mm. in width. Bleeding was usually abundant. These cavities were then packed with small pledgets of oxidized cotton. The material was very easy to handle, almost immediately transforming itself into a dark paste which was easy to mold into the cavity, and the hemostatic effect was always very satisfactory. These animals were sacrificed at 14, 37, 40, 42, 103, 103 and 134 days, respectively. As shown in Table I, gross evidence of regeneration of bone was absent until the 42nd day, while at 37 days there was microscopic evidence of proliferation of osteoid. Prior to this date the drill holes were filled by dense fibrous cicatricial tissue showing no tendency towards ossification and containing the basophilic phagocytes characteristic of the tissue reaction to oxidized cellulose.

Because these results suggested that the material under study delayed the

*The work described in this paper was done under a contract recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and Columbia University. The gauze and cotton were supplied by Eastman Kodak Research Laboratories, Rochester, N. Y. (U. S. Pat. No. 2,232,990) through Parke, Davis & Company, Detroit, Michigan.

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ABSORBABLE GAUZE IN BONE SURGERY

healing of bone, we started a new series of experiments, in order further to investigate the influence of oxidized cellulose on bone repair. After exposing the anterolateral surface of the upper half of the radius as in the previous group of experiments, a fracture was produced with the aid of strong bone-cutting forceps. The bone can not be cut at once, with one single stroke of the instrument, but must be gradually divided, biting a few millimeters at a time. In some instances, instead of a single fracture line, we obtained comminuted

TABLE I
DRILL HOLES IN RADIUS

S.P.	Days	Material	Repair					
			X-ray	Gross	Micro.	Phagocytes	Polys.	Absorption
22312	14	Oxidized cotton	-	-	-	+	-	-
22383	37	Oxidized cotton	- +	-	+ -	-	-	+
22356	40	Oxidized cotton	+ -	-	+ -	+	-	+
22371	42	Oxidized cotton	+	+	+	+	-	+
22637	103	Oxidized cotton	+	+	+	+	-	+
22638	103	Oxidized cotton	+	+	+	+	-	+
22619	134	Oxidized cotton	+ -	?	+ -	+	-	+

TABLE II
FRACTURES OF RADIUS

S.P.	Days	Material	Repair					
			X-ray	Gross	Micro.	Phagocytes	Polys.	Absorption
22876	7	Control	-	-	+ -	-	-	-
22900	14	Control	-	+	+	-	-	-
22839	14	Oxidized gauze	-	-	- +	+	-	+
22935	15	Oxidized gauze	-	-	-	+	-	+
22875	21	Oxidized gauze	-	-	-	+	-	-
23114	68	Control	+	-	+	-	-	-
23113	91	Oxidized gauze	-	+	- +	-	-	+
23035	12	Fibrin foam	-	-	- +	-	-	-
23076	17	Fibrin foam	-	-	- +	-	-	-
23201	56	Fibrin foam	+	+	+	-	-	+
23244	70	Fibrin foam	+	+	+	-	-	+

* In these two cases a cystic cavity was found.

fractures in which the bone was broken in several fragments. In this group 11 dogs were used. Of these, three were used as controls and were sacrificed at seven, 14 and 68 days. In four animals, killed at 14, 15, 21 and 91 days, the site of the fracture was packed with oxidized gauze, and in the other four, killed at 12, 17, 56 and 70 days, fibrin foam soaked in thrombin was used. In each instance the sponge was introduced between the fracture fragments and also packed against the denuded surface of the radius, *i.e.*, about one-half of its circumference and approximately 2.5 cm. of its length (Table II). The soft tissues were then approximated with two fascial stitches and the skin closed with interrupted sutures.

As for the physical properties of the materials used, there is no doubt in our minds that oxidized cellulose sponges as compared with fibrin foam sponges

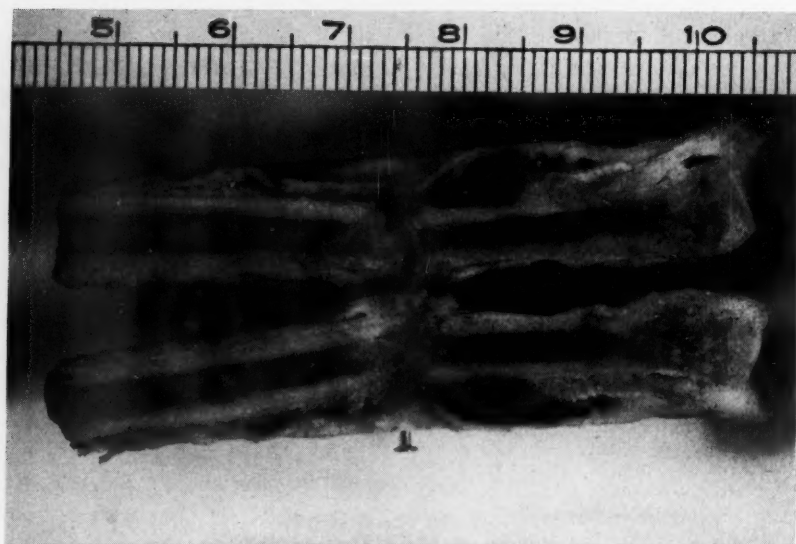


FIG. 1.—S. P. 22889: Autopsy specimen two weeks after experimental fracture of radius in which oxidized gauze was introduced between the fragments and around part of the circumference of the bone. Note cavity between the fragments and between bone and soft parts.



FIG. 2.—S. P. 23113: Low power photomicrograph of radius 91 days after experimental fracture in which oxidized gauze was used. Note practically complete lack of bone or osteoid callus. Only union between fracture fragments is made up of dense fibrous tissue and cartilage. (See also Fig. 3.)

soaked in thrombin, are much easier to handle and to pack in the crevices of the bone. Furthermore, when using fibrin foam one must allow for extra time for the preparation of the solution of thrombin and for soaking the dry fibrin sponge in the thrombin solution. Table II shows that bone repair, when compared with the healing of the control fractures, was delayed in both the oxidized



FIG. 3.—S. P. 23113 (left) and 23114 (right): Roentgenograms of autopsy specimens of left and right front legs of same animal. Left side shows no radiologic sign of callus *three months* after experimental fracture in which oxidized gauze was used. Right side shows calcified callus in *two-months'-old* fracture of radius in which no absorbable material was used.

cellulose and fibrin foam groups. No attempt is made here to compare the effect on bone healing of these two types of sponge as to their relative time factors.

However, we want to describe in detail two cases. In one case (S. P. 22889) a cyst-like cavity containing remains of oxidized cellulose was found surrounding the fracture at 14 days. The portions of bone shaft contained in this cavity appeared free of any soft tissue attachment and did not show gross signs of repair (Fig. 1). Microscopically, a minimal amount of osteoid was present together with the usual typical phagocytes. Another case (S. P. 22935), sacrificed 15 days after production of fracture using oxidized gauze in the

manner described, showed a similar cavity which was lined by flattened cells, making it resemble an adventitious bursa. Also here, there were minimal, if any, microscopic signs of bone repair. No such cavities were observed in the cases in which fibrin foam had been used.

In the cases followed for a longer time where repair had eventually taken place, the osteoid callus was mostly periosteal while between the fracture fragments the union had occurred predominantly by way of fibrous and cartilaginous tissue (Fig. 3). Altogether, reparative tissue in this group of experiments seemed to contain more abundant osteoid in the cases treated with fibrin foam than in those in which oxidized cellulose was used. We realized, however, that individual difference in type and rate of healing as well as differences in the type of fracture obtained might well account for the apparent advantage in favor of fibrin foam. In some of the cases, the lack of proliferation of osteoid was particularly striking in proximity to the collections of basophilic phagocytes typical of the tissues in which oxidized cellulose has been introduced. We shall return later to this interesting point.

These preliminary results induced us to attempt to devise a type of experiment in which we could compare, in the same animal, the influence on bone healing of different types of absorbable materials. This would eliminate the rôle played by possible individual differences in tissue reactions and would also allow the use of a smaller number of animals than would be otherwise required. The method we used, which in our opinion, was satisfactory is as follows:

Under intravenous anesthesia with nembutal, the animal was placed on its left side. The right hemithorax was shaved and prepared. Three or four ribs (6th to 9th) were identified by palpation and their place marked on the skin with gentian violet. An oblique incision, about 7 cm. long, was then made running cephalocaudad and postero-anteriorly, approximately between the posterior and the anterior axillary line. The anterior margin of the latissimus dorsi muscle was then identified, the muscle was retracted backward and, after incising the underlying loose areolar tissue, the ribs were easily exposed. The periosteum was then incised and stripped away all around the bone for a length of 3 cm. With some care and patience, this maneuver is easily executed without perforating the underlying parietal pleura which is very thin. With bone-cutting forceps, and while protecting the pleura with the handle of a scalpel, a linear fracture of the ribs was then produced. The absorbable material was then packed between the fracture fragments and wrapped around the portion of bone denuded of periosteum. No attempt was made to close the periosteum over the fractured ribs, but the loose overlying areolar tissue was approximated with two or three fine silk stitches. A similar control fracture was made in which no absorbable material was used. The latissimus dorsi muscle was then replaced so as to cover the sites of fracture and anchored with a few interrupted sutures. The skin was closed with a running stitch.

We performed this operation upon eight dogs. In none was the pleura damaged and all survived, showing only signs of mild respiratory distress for

ABSORBABLE GAUZE IN BONE SURGERY

the first two or three days. No pleural effusion was found in any of them at autopsy. As Table III shows, in four of these animals, sacrificed at 8, 24, 42 and 52 days, oxidized cellulose and fibrin foam were tested; in the other three, sacrificed at 21, 42 and 56 days, fibrin foam and absorbable gelatin sponges soaked in thrombin were used. In all animals one of the fractured ribs was used as control. In the eighth dog, in four ribs instead of fracture a segment 1 cm. long was resected and the gaps thus obtained were filled with oxidized

TABLE III
EXPERIMENTAL FRACTURES OF RIBS

S.P.	Days	Material	Repair			Phago- cytes	Polys.	Absorp- tion	Remarks
			X-ray	Gross	Micro.				
23019	8	Fibrin foam	-	-	-	-	-	-	
	8	Ox. gauze	-	-	-	+	-	+	Cystic cavity
	8	Control	-	-	+	-	-	-	Some osteoid
23100	24	Fibrin foam	+	-	+	-	-	+	Osteoid and cartilage
	24	Ox. gauze	-	-	-	+	-	+	Cystic cavity, some periosteal osteoid
23165	24	Control	+	-	+	-	-	-	Osteoid and cartilage
	42	Fibrin foam	+	+	+	-	-	+	Osteoid, cartilage and fibrous tissue
	42	Ox. gauze	-	-	-	+	-	+	Almost entirely fibrous callus
23229	42	Control	+	+	+	-	-	-	Osteoid, bone and cartilage
	52	Fibrin foam	+	+	+	-	-	+	Union: Bone and osteoid
	52	Ox. gauze	-	+	-	+	-	+	Cartilage and fibrous tissue
23323	52	Control	+	+	+	-	-	-	Bony union
	21	Fibrin foam	-	-	+	-	-	-	Some periosteal osteoid and cartilage
	21	Gelatin	-	-	+	-	-	-	Some periosteal osteoid and cartilage
23422	21	Control	-	+	+	-	-	-	Some periosteal osteoid and cartilage
	42	Fibrin foam	+	+	-	+	-	+	Osteoid and cartilage
	42	Gelatin	+	+	-	+	-	+	Osteoid, cartilage and some bone necrosis
23479	42	Control	+	+	-	+	-	-	Osteoid and fibrous tissue
	56	Fibrin foam	+	+	+	-	-	+	Bone and cartilage
	56	Gelatin	+	+	+	-	-	+	Bone and some cartilage
23491	56	Control	+	+	+	-	-	-	Bone and fibrous tissue
	56	Fibrin foam	+	-	+	-	-	+	Little osteoid, cartilage and scar
23491	56	Gelatin	+	-	+	-	-	+	Little osteoid, cartilage and scar
	56	Gauze	-	-	+	+	-	+	Mostly fibrous callus
23491	56	Control	+	-	+	-	-	-	Large callus, osteoid and cartilage

RESECTION OF SEGMENT OF RIB

gauze, fibrin foam or absorbable gelatin sponge. At autopsy, the fracture sites when examined from the pleural surfaces, presented themselves as rounded swellings covered with shining pleura. These swellings were due in part to the callus, but in great part also to some overlapping of the fractured ends present in all cases, presumably caused by the respiratory movements and by the contractions of the intercostal muscles.

In spite of the fact that oxidized cellulose was the material that apparently was absorbed in the shortest period of time (absorption almost complete at eight days as compared with 21 days for fibrin foam and gelatin sponge), the

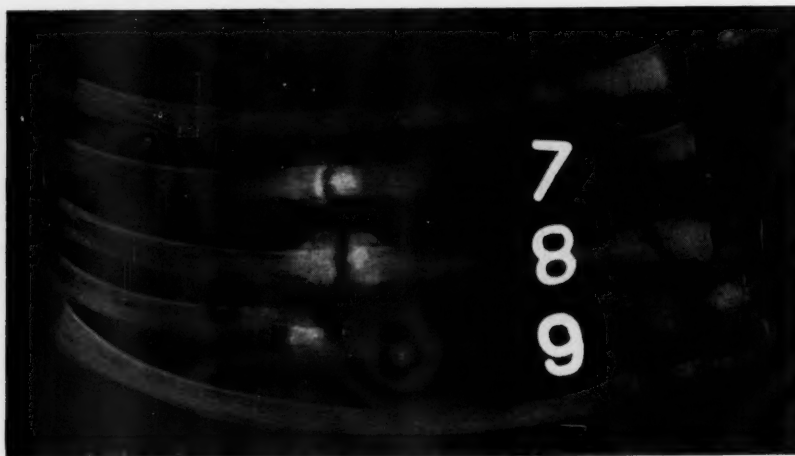


FIG. 4.—S. P. 23165: Roentgenogram of autopsy specimen 42 days after experimental fracture of ribs 7, 8, 9. Note the fairly good calcified callus in ribs 7 (fibrin foam) and 8 (control) as compared with the malunion at 9 (oxidized gauze).



FIG. 5.—S. P. 23229: Roentgenogram of autopsy specimen 52 days after experimental fracture of ribs 7, 8, 9. Note the excellent callus at ribs 7 (fibrin foam) and 8 (control) as compared with the incomplete calcified callus at 9 (oxidized gauze).

reparative processes were consistently slowed down in the fractured ribs in which oxidized cellulose was used. In all cases, from eight to 56 days, these ribs when examined at autopsy showed some persistent mobility at the frac-

tured site and roentgenograms showed that the amount of calcified callus was always less than in the controls and in the fractures in which one of the other two absorbable materials had been used (Figs. 4 and 5). Microscopically

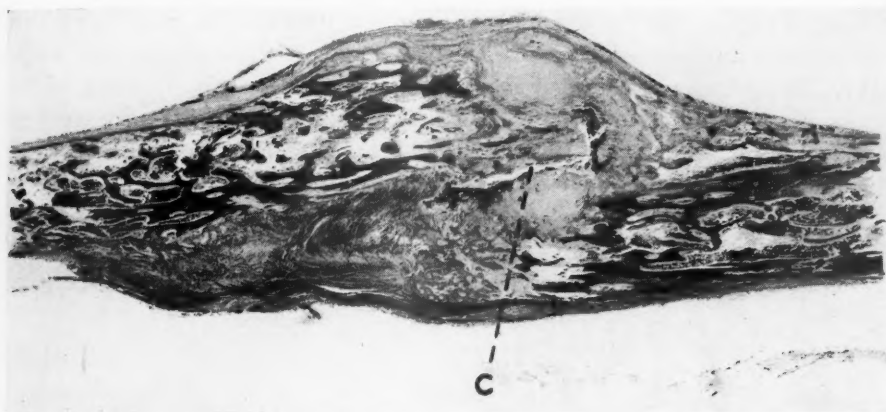


FIG. 6.—S. P. 23229: Low power photomicrograph of 9th rib 52 days after experimental fracture in which oxidized gauze was used. Note scanty osteoid. The tissue which joins the bone fragments consists mainly of fibrous tissue and few islands of cartilage. A small cavity is still present (C).

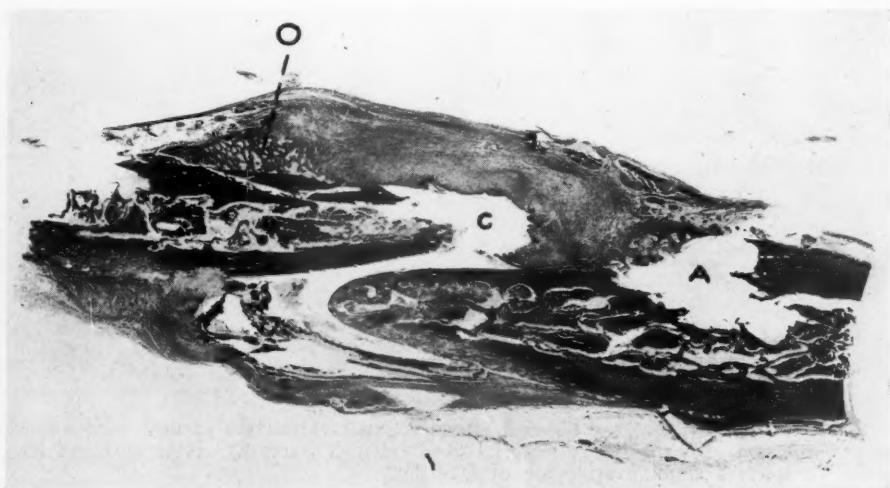


FIG. 7.—S. P. 23100: Low power photomicrograph of a fractured rib 24 days after experiment. Oxidized gauze was used in this rib. Note cavity (C) surrounded by a fibrous tissue capsule and containing the free ends of the fractured rib. Except for a small area of osteoid at (O) there is no histologic sign of bone repair. The space (A) is an artefact. Controls: (not illustrated) Simple fracture and fracture with fibrin foam interposed showed no cavity (See Table III).

(Fig. 6), the amount of osteoid in the callus was always minimal and the repair occurred mostly through fibrous scar containing islands of hyaline cartilage. In the dog sacrificed at the 8th day, necrotic portions of bone could be

seen in the area where the absorbable material had been contained. Furthermore, in two cases (eight and 24 days) a cyst-like cavity was found surrounding the fractured ends, resembling those that occurred in the experiments already described with oxidized gauze in the fractured radius (Fig. 7). The healing of the fractures in which fibrin foam was used did not, in these experiments, show any appreciable delay as compared with the controls (see Table III). No cavities were formed around the fracture sites, the mobility of the fragments was almost absent starting at 24 days and the roentgenographic features of the callus were comparable with those of the control fractures at



FIG. 8.—S. P. 23229: Low power photomicrograph of 7th rib 52 days after experimental fracture in which fibrin foam was used. Note the excellent bony union in spite of the overlapping of the fragments.

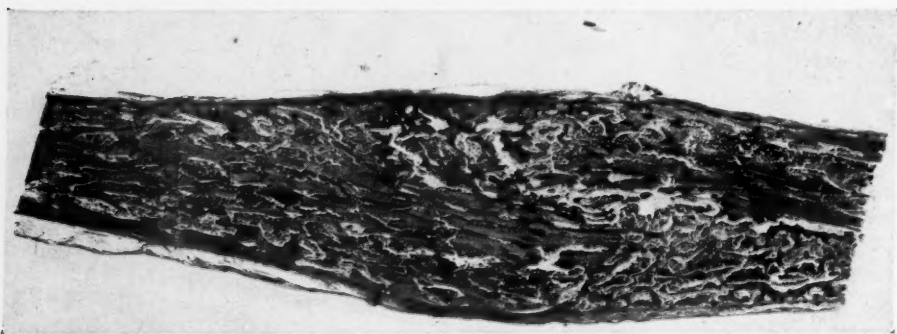


FIG. 9.—S. P. 23229: Low power photomicrograph of 8th rib 52 days after experimental fracture. No absorbable material used (control fracture). Note excellent bony union in spite of slight overlapping of fragments.

corresponding dates (Figs. 4 and 5). Microscopically (Figs. 8 and 9), the reparative process did not seem to be interfered with by the presence of fibrin foam. As a matter of fact, in one instance (eight days) there was evidence of invasion of fibrin foam by the fibroblasts of the host, as would be expected to occur in autogenous fibrinous clot.

Those fractures in which the absorbable gelatin sponge was used showed, in our experiments, a slight delay in healing as compared with those treated

with fibrin foam and with the controls, but in no case as marked as those treated with oxidized cellulose. Some mobility of the fragments was still present at 42 days, but at this date the roentgenograms already showed a good callus. The reparative process consisted of good proliferation of osteoid, cartilage and fibrous tissue without signs of irritation by the foreign material (Fig. 10).

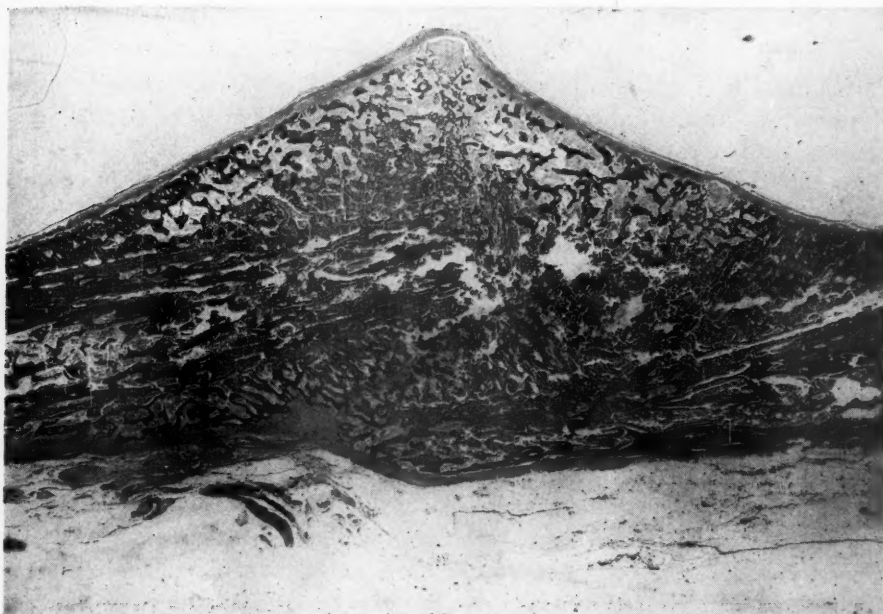


FIG. 10.—S. P. 23479: Low power photomicrograph of rib 56 days after experimental fracture in which absorbable gelatin sponge (Gelfoam) was used. Good bony and osteoid union.

COMMENT.—There seems to be little doubt that the presence of oxidized cellulose in the immediate vicinity of a fracture interferes with the normal processes of repair of bone. By what mechanism does this occur? The material is slightly acid and it probably retains its acid reaction even after having been partly broken down and phagocytized. This is suggested by the fact that the cytoplasm of the characteristic phagocytes, which are present in tissues following introduction of oxidized cellulose, is always more or less basophilic. These phagocytes disappear from the tissues very slowly. In these bone experiments, some phagocytes were still to be seen in the specimens of animals sacrificed 56 days after operation. It is also worthy of mention that in several of our microscopic preparations we had the impression that the least bone repair occurred in proximity to the collections of these basophilic cells. It becomes natural, therefore, to think that the interference with bone healing might depend on a low local pH . This would almost certainly damage already formed bone and interfere with the concentration of inorganic calcium salts,

which is a prerequisite for the formation of new bone. It is also possible that there is interference with activity of the bone phosphatase. We have, however, made no *pH* determinations nor phosphatase determinations in the tissues in these experiments.

From these results we must conclude that in clean bone surgery in which rapid formation of callus is desired, the use of oxidized cellulose as hemostatic packing is contraindicated. Fibrin foam or absorbable gelatin sponge soaked in thrombin are certainly preferable.

For hemostasis in open contaminated or infected wounds of bone oxidized gauze could be used as a temporary packing of large bleeding cavities. As already explained, in preceding publications, it has the advantage of easy removal without causing further bleeding. Furthermore, because of its solubility in the tissue fluids, it never acts as a cork which would transform an open contaminated wound into a closed infected cavity.

Recognition of the peculiar property of oxidized cellulose, *i.e.*, that of interfering with the repair of bone, without any further harmful effects on the tissues immediately suggested its use whenever it is desirable to prevent or at least to delay ossification.

Many applications can certainly be found. The most important one in our opinion is the use of oxidized cellulose in the surgical reconstruction of ankylosed joints, or in general, in those surgical procedures in which the possibility of a postoperative ankylosis is envisaged.

Following our suggestion, arthroplasty operations employing this absorbable material have already been performed by some surgeons associated with this institution. The results to date, judging from the preliminary communications that we have received, are encouraging.

SUMMARY

Oxidized cellulose, fibrin foam, and absorbable gelatin sponges have been used in experimental fractures of bones, and their effects on bone healing have been compared. Oxidized cellulose, possibly because it lowers the local *pH*, interferes considerably with the repair of bone. The utilization of this property of oxidized cellulose is suggested in arthroplasty procedures and other bone operations in which a delayed ossification is desirable.

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MANAGEMENT OF LATE HEAD INJURIES

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CERTAIN TECHNICAL ADVANCES have appeared since World War I, which not only allow a more refined neurologic diagnosis, but also considerably facilitate the neurosurgical management of cranial wounds sustained as the result of modern warfare. The former include encephalography, ventriculography and electro-encephalography. Among the latter are electrocoagulation and fibrin foam for hemostasis; tantalum foil and fibrin film as dural substitutes (and to minimize meningocerebral cicatrices); tantalum plate for cranioplasty; and the sulfonamides and penicillin for prophylaxis and control of infection.

These methods were at first available only in the various Neurosurgical Centers in the Zone of Interior. However, in the later phases of the European and Pacific Theaters of Operation, these procedures and materials were utilized in several designated General Hospitals overseas. Fibrin foam was also distributed to the various surgical auxiliary units and a portable electro-encephalogram was being investigated for use in the Field.

A considerable number of casualties with cranial defects and neurologic sequelae have been evacuated to the States for further neurosurgical diagnosis, treatment and rehabilitation. It is not our purpose to review the literature on this subject at the present time; rather we wish to state our experiences in the management of these conditions and the results obtained.

These studies were carried out initially at Brooke General Hospital, Fort Sam Houston, Texas, beginning in April, 1942 and continued at McGuire General Hospital, Richmond, Virginia, on the transfer of the writers in February, 1945. Complete investigation of each patient from every standpoint, including electro-encephalography and encephalography was made on admission.

We have now had experiences with 254 cranioplasties, in which tantalum was used for repair. Two hundred thirty-eight were secondary to craniocerebral injuries, 187 of which were a direct result of wounds sustained in action. The majority of this group were due to shell fragments, preliminary débridement having been accomplished overseas. All defects measuring 3.5 cm. or more in diameter, were revised according to present Army regulations, as well as taking into consideration the usual indications for operation, including the smaller deformities. The remaining procedures were performed after craniotomies for the following conditions: Trigeminal neuralgia, 4; osteomyelitis, 3; osteoma, 3; increased intracranial pressure, 2; meningioma, 2; eosinophilic granuloma, 1; and abscess, 1.

The majority of our earlier cases were repaired under a general anesthetic, and this method is still preferred in those defects involving the squamous portion of the frontal bone. Novocaine local anesthesia has been used in the other

LATE HEAD INJURIES

patients. The previous craniotomy incision had usually been irregularly linear or triradiate in appearance and was generally suitable for operative exposure. Old scars were revised and plastic surgery was performed as indicated, taking care not to create too much tension during closure of the wound, which predisposes to incisional necrosis and secondary infection. An occasional horseshoe-type scalp flap may be necessary, particularly, in those deformities involving the squamous portions of the temporal bone for adequate exposure. However, this incision should be avoided if incorporating a significant amount of scar in its base due to possible subsequent necrosis from inadequate blood supply. This was well demonstrated in one of our cases, in which the skin flap had to be subsequently replaced by a split-thickness graft.

Following retraction of the skin edges, the periosteum is carefully separated from the underlying dura, insofar as this is possible. The pericranium can then be sutured over the plate as a separate layer during closure for additional fixation and protection. We have entered the dura in 79 instances and introduced tantalum foil in the subdural space. Decision in this respect will depend upon the size and shape of the defect, proximity to the venous sinuses, electroencephalographic and encephalographic findings, focal signs and symptoms, amount of gross scar at operation, presence of complications, such as infection, *etc.* The advantages derived from opening the dura are numerous. It allows a more accurate evaluation and estimation of prognosis in a given individual, such as those with dysphasia, hemianopsia, *etc.* It facilitates the treatment of such conditions as cerebrodural and cortical scars, porencephaly, *etc.* It discloses the actual site of pathology, allowing inspection, palpation, careful exploration of the extent of the lesion with the ventricular needle and biopsy if desired, thus, supplementing the electro-encephalogram, encephalogram and neurologic examination. It allows the removal of bony or metallic foreign bodies in presence of infection or focal signs. We have preferred to use tantalum foil in all cases, in which the dura has been entered, to prevent further development of a meningocerebral cicatrix, as previously outlined.¹¹ Fibrin film would serve a similar purpose, but is not as yet commercially available. Tantalum foil has been used in contaminated fields without difficulty, but rarely suppuration will occur, necessitating removal, as shown in two of our cases. Further, infection has occurred as often epidurally without extension into the subdural space in the presence of foil, so this factor alone should not contraindicate its use.

In those cases in which the dura has been entered there have been varying degrees of cerebrodural scar present. This is always carefully dissected free in all directions within and beyond the confines of the incision. This is facilitated by removal of ventricular fluid. The significance of this procedure will be difficult to determine until a long term follow-up on the cases studied can be accomplished. It is expected that although a cortical lysis has been performed which operates to reduce the possibility of posttraumatic complications, such as epilepsy, headaches, *etc.*, these conditions may well develop later from a scar within the brain substance itself.

Relatively early resection of this meningocerebral cicatrix, or its avoidance by application of a dural substitute at the time of injury, with complete primary excision of contused and lacerated brain, when and where possible, may do much to obviate the development of intrinsic cortical scar. This process, once started, tends to increase through the years by extension of blood supply and connective tissue from the meninges to the underlying cortex. Although long-term results are not available in these cases, it is felt that cortical excision for focal epilepsy will not only tend to reduce the actual number of seizures, but also facilitate the medical management with anticonvulsive therapy. Prophylactic surgical therapy in patients presenting focal electro-encephalographic, encephalographic and neurologic evidence of epileptogenic lesions, but without clinical seizures has not as yet been attempted.

The preparation and insertion of tantalum has been described previously by one of us,¹⁰ and more recently by Woodhall and Spurling,¹¹ who further include the various indications and other methods of cranioplasty. Their series of 79 cases is the largest yet published and the results have been quite satisfactory.

A one-stage procedure is preferred in our cases. Only two of the earlier patients were operated upon in two stages. There appears to be no particular advantage in preparing the plate preoperatively or fabrication at the time of surgery, an equal number of each being on record in our series. The former method conserves time, but occasionally, even when a model has been carefully made, the tantalum is found to be unsatisfactory at operation. This is particularly true in those deformities involving the squamous portions of the frontal bone, including the supra-orbital ridges, which are difficult to restore to perfect anatomic continuity. Preparation of the plate at operation will have its greatest advantage in the immediate repair of acute head injuries. One should develop the facility of beating plates to contour because of such situations.

The inlay technic, in which the plate was inserted in a ledge created along the presenting outer table of the bone with further fixation by tantalum wedges was followed in the first 180 cases. A secondary repair for slipping of the tantalum was necessary on two occasions in our early experience. We have recognized no gross operative or neurologic residuals following the manipulations necessary during the above described procedure. The remaining skull defects were repaired by the onlay technic. In these instances the plate is fashioned in the usual manner, slightly larger than the defect over which it is placed, with or without fixation (tantalum wedges, screws or wire). We have used wedges throughout in lieu of wire. Screws have not as yet become generally available. This, again, is a more rapid method and especially adapted to the treatment of acute craniocerebral wounds, and in those situations in which the presenting bony margins are extremely thinned, such as the squamous portions of the temporal bone. However, the inlay technic is still preferred in the supra-orbital defects because of the more satisfactory cosmetic result obtained.

We can see no advantage in perforating the tantalum plate. This has been suggested to allow fluid interchange, to allow scar formation between the scalp

and dura and to facilitate the administration of penicillin in event of an infection. It has also been demonstrated that tantalum can be used effectively in soiled fields,¹⁰ but the pre- and postoperative preparation of the patient with sulfadiazine and/or penicillin must be stressed. Further, although not invariable, it has usually been necessary to remove the plate once infection has occurred following cranioplasty.

We must reemphasize the necessity of exenterating the mucous membrane of the frontal sinus and occluding the ostium of the nasofrontal duct to avoid a potential source of infection. One case was unsuccessfully revised on two occasions for an extradural pneumatocoele and finally controlled only after scarifying the nasal opening of the passageway from the frontal sinus.

Many of these cases have collected subgaleal and subcutaneous fluid postoperatively in spite of careful hemostasis, closure and compressive dressings. Repeated aspiration under questionably aseptic conditions may possibly have led to infection in two cases, although there is always a possibility of latent organisms at time of operation. We have accordingly drained our more recent cases for 24 to 48 hours, with satisfactory results.

We wish to comment on the rarity of cases evacuated to us with brain abscess or cerebral hernia, which has been felt due to careful, thorough preliminary débridement.

The electro-encephalogram has been of considerable value in cases of this type, particularly in the detection of subclinical epilepsy. Experience in the interpretation of this procedure is essential, however, if it is to be relied upon for diagnosis and prognosis.

Encephalography has been performed routinely in all our cases, and we have found it helpful in giving additional useful information, such as presence of ventricular shift, porencephaly, internal hydrocephalus, *etc.*, which may alter the subsequent operative procedure. The lumbar route, under pentothal anesthesia, has been used, although some prefer the cisternal technic to minimize reaction. We have further prepared the scalp the morning of the encephalogram and proceeded with the cranioplasty the following day in many of these cases without intensification of symptoms, and this sequence also shortens the actual length of hospitalization. Tapping of the ventricle at cranioplasty further tends to diminish postoperative headaches by release of the previously injected air or oxygen.

The neurologic residuals include the various signs and symptoms dependent upon the site of central nervous system trauma and the degree of permanence can usually be estimated three to four months following the trauma. These do not include the possibility of convulsions or the period of improvement which will result from the intelligent and intensive rehabilitation of speech. The latter often requires one to two years. All patients receive intensive reconditioning, including an educational, vocational and recreational program, together with occupational and physical therapy as indicated prior to completion of maximum benefit of hospitalization.

The various manifestations of posttraumatic syndrome are well known to

neurologists and neurosurgeons. These symptoms are not often observed after the more severe penetrating gunshot wounds. So-called blast concussion, with residuals, has only occasionally been seen. Posttraumatic personality disorders and mental deterioration are usually directed to the neuropsychiatric centers.

All cases of posttraumatic syndrome are carefully evaluated and every effort is made to determine the presence of structural damage unless the patient is obviously psychoneurotic. History of loss of consciousness, retrograde and posttraumatic amnesia, bleeding from the orifices and presence of focal or general neurologic signs and symptoms are important. Much objective information can be gained from previous overseas records, such as roentgenographic evidence of fracture, bloody spinal fluid, *etc.* The electro-encephalogram and encephalogram, when positive, furnish tangible data of organic damage. Spinal fluid pressure and chemistry have usually returned to normal when these cases are received two to three months after injury. We have not been impressed with localized headache as evidence of this syndrome.

The use of prostigmine in postconcussion headache and vertigo was recommended by Malone,⁶ on the supposition that its vasodilator properties would relieve the intracranial vasospasm. Ten cases were cited, in which relief was obtained. Friedman and Brenner,³ suggest that a localized vascular sensitivity results from trauma, as demonstrated by histamine studies. We have used prostigmine and histamine in alternate cases in a series of 50 patients. Seven of these treated with prostigmine stated there was temporary relief, lasting usually one to two months, but recurrence was present in all. Histamine desensitization gave negative results throughout. Erythritol tetranitrate was given in 25 additional cases for its vasodilator properties. Slight improvement was seen in one patient. Although it is recognized that disturbances in the vasomotor system are present in some patients of this type, these drugs are no longer routinely administered, as so many secondary factors are present that adequate evaluation is not possible.

Sporadic reports have appeared during the past 20 years, directing attention to the therapeutic value of encephalography in posttraumatic symptoms. The most recent include studies by Maass and Patino,⁵ Castaneda,¹ Horrax,⁴ and Mayfield.⁷ Long-term follow-ups, however, have not appeared. Relief has been explained by the air tension releasing adhesions between the arachnoid and dura. Maass and Patino further recommend this procedure in the prevention of the latter complication in cases of recent head injuries. Davidoff and Dyke,² however, feel it of value only in a few selected cases. Penfield,⁸ suggested treating these sequelae by spinal or cranial subdural insufflation of air. Early reports were encouraging as to relief from these symptoms.⁹ Ross and McNaughton,¹² studied 82 patients from Penfield's Clinic, and concluded that the long-term results were no better than those seen following pneumo-encephalography.

We have now had experience with 125 cases treated by pneumo-encephalography. Only five have mentioned relief over a period of three months observation. We have had no experience with spinal or cranial insufflation. An

LATE HEAD INJURIES

occasional patient has obtained relief following cranioplasty (syndrome of the trephined).

It would, therefore, appear that there is no specific method of treating posttraumatic states, possibly due to the close association of physiologic and psychologic factors, as suggested by Symonds.¹³ We have come more and more to rely upon intelligent handling of the patient, early ambulation, sedation, psychotherapy and well-directed efforts at rehabilitation. This should include a well-organized program with graduated physical and educational facilities.

SUMMARY

We have now used tantalum satisfactorily in the repair of 254 cranial defects. The various methods of preparation and fixation appear to give equally good results. There is no specific medical or surgical treatment for the numerous manifestations of posttraumatic syndrome. Intelligent, judicious management with reassurance, early ambulation, mild sedation, as indicated, and an intensive reconditioning program have given more favorable results than any other method in our experience.

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THE TECHNIC OF IMMEDIATE RESTORATION OF VASCULAR CONTINUITY AFTER ARTERIAL WOUNDS

INDICATIONS AND RESULTS

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WHEN CONFRONTED with the problem of revascularizing the dangerously ischemic limb, one is at once impressed by the unsolved problems in anatomy, physiology and pathology. It is, therefore, essential to define the extent of ischemia affecting the wounded extremity. The dangerously ischemic limb is one which has been deprived of its blood supply to such an extent that vital processes no longer take place and gangrene results. The forerunner of this state is ischemia, and whether the ischemia progresses to recovery or not depends upon the volume of blood the limb receives, the pressure at which it is delivered, the length of time the ischemic state has existed, and the metabolic demands of the limb itself. It is only by a consideration of the general condition of the patient, the time interval, and both the function and appearance of the limb that the degree of ischemia can be determined. The variability of the circulation through the main and collateral channels renders dogmatic anatomic statements worthless. Even though the distal pulses are absent it is reasonably certain that a limb will survive if active movement of the digits is present and the digital skin has some warmth, some sensation, and is not of an unnatural color. If, however, active motion of the digits is no longer present and the digital skin is cold, insensitive, and of an unnatural color, then the limb is dangerously ischemic.

Active surgical interference is to be avoided, when possible, if recovery of the limb is to be expected. In the dangerously ischemic limb, however, operation becomes a matter of some urgency whatever the local arterial lesion. In the absence of arterial spasm and of occlusion of the vessel by extravascular compression, the type of surgical intervention is limited to ligation or some attempt at reestablishing the circulation.

SURGICAL PROCEDURES

Ligation.—Ligation of the main vessel removes the hazard of further bleeding but does little to improve the blood supply of the limb. Experience has shown us that it is the procedure of choice in certain circumstances:

1. As a life-saving measure.
2. If heparinization is impractical:

The administration of heparin requires qualified supervision including careful nursing and repeated estimations of the clotting time; it is contraindicated in multiple wounds and in wounds involving the cranial, pleural, or abdominal cavities.

RESTORATION OF VASCULAR CONTINUITY

3. If the limb has been avascular longer than ten hours:

The survival time of avascular tissue has been investigated by many observers and the general view (with which my own opinion coincides) is, that if warmth to the limb is avoided, skin will survive at least 24 hours, muscle 6 to 10 hours, and nerve perhaps a shorter period.

4. If trauma has been extensive:

Experience with traumatic amputations and with crush injuries would lead one to believe that no attempt at revascularizing a crushed limb should be made until more is known of this pathologic condition.

5. In the upper extremity:

The collateral circulation in the arm is rarely sufficiently damaged to warrant anastomosis of the main vessel.

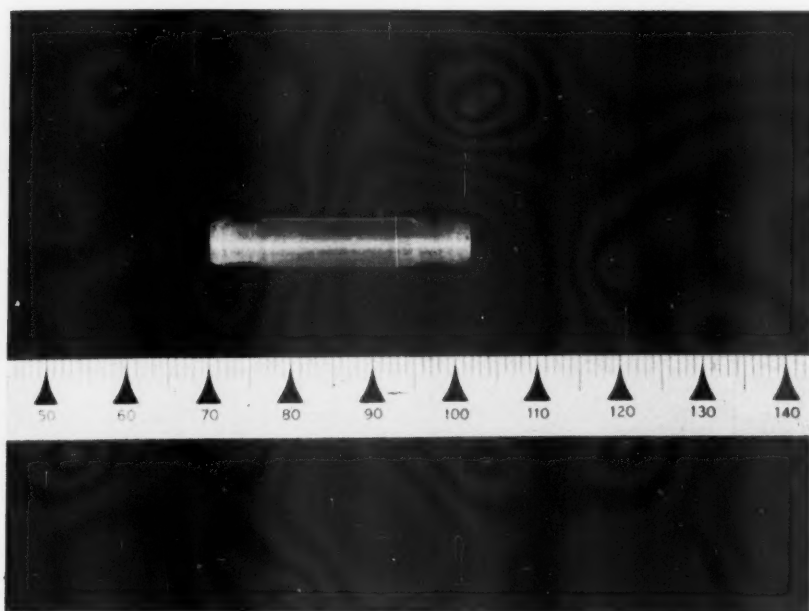


FIG. 1.—Case 15: Plastic tube removed at operation.

Anastomosis.—Reestablishment of the circulation in the dangerously ischemic limb is a practical procedure and may be accomplished by any of the classical methods. Axial anastomosis and suture of the partially divided vessel are ideal but impractical methods which I have not attempted. The insertion of a primary venous graft is a difficult procedure and should be considered an elective operation.

It has been demonstrated experimentally by Murray and Janes,¹ that a glass cannula in the lumen of an artery will remain patent in a heparinized animal, and I have extended this observation to man. Glass tubes are convenient because of their inertness and various lengths and calibers are readily obtainable.

These tubes must, of necessity, be smaller than the lumen of the vessel (since they lie within) and thus stimulate the formation of a collateral circulation. It is preferable to have a small shoulder near each end of the tube and excellent tubes of plastic material are now available (Fig. 1). At the time of operation a wide assortment of tubes should be sterilized since the separation of the ends of the divided vessel is often of surprising extent.

Technic in Complete Division.—The approach to the artery should be made carefully in order to preserve the collateral vessels; the ends are identified and cleared of thrombus, bleeding being controlled by tourniquet or bulldog

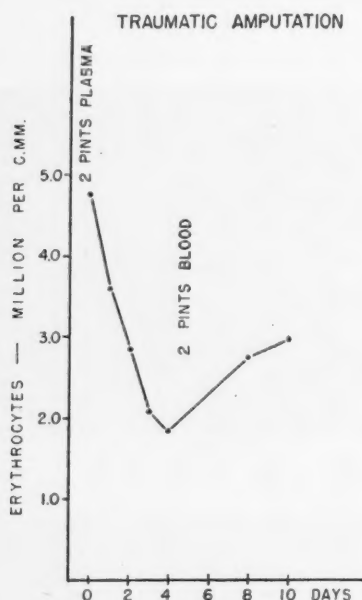


FIG. 2

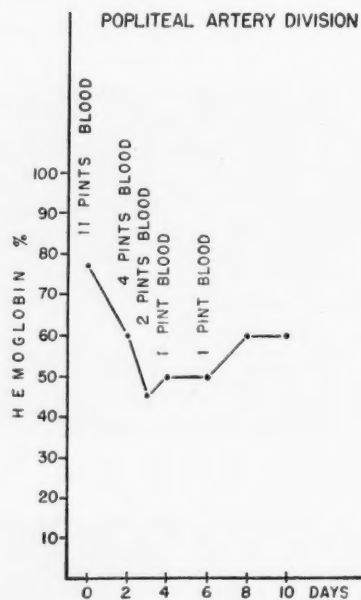


FIG. 3

FIGS. 2 and 3.—Hematocrit readings and blood volume studies in severe wounds.

clamps. The accompanying vein is ligated if damaged and preserved if intact. The distal arterial tree is perfused with heparin solution (1 cc. to 100 cc. saline) and with the intima well visualized, three stay-sutures of fine silk are placed in each open end. The tube is then prepared; it should be as short as possible and fit easily into the arterial lumen; after thorough cleansing it is filled with liquid paraffin, washed out with heparin solution and finally filled with the solution. It is inserted into each end of the divided vessel (care being taken not to strip the intima) and the distal stay-sutures tied to the proximal. Two encircling ligatures (linen or silk) are tied snugly about each shoulder of the tube. Thirty to forty cubic centimeters of heparin solution are injected through a fine needle into the vessel proximal to the tube as the distal clamp is released, the injection continued as the proximal clamp is re-

RESTORATION OF VASCULAR CONTINUITY

moved. Immediately following this local or regional heparinization, intravenous heparin solution at the rate of 30 to 40 drops per minute should be commenced. With the reestablishment of circulation there is considerable venous bleeding and it is well to control this carefully.

Technic in Incomplete Division and Traumatic Thrombosis.—In incomplete division the tube is slipped into the lumen after clearing the adventitia and encircling ligatures only are needed. If the lesion is traumatic throm-



FIG. 4.—Case 10: Note length of graft.

bosis, it is wise to place a cannula across the contused segment to add strength to the vessel wall, and to offer a smooth surface to the blood stream. A longitudinal incision is made through the contused area and the thrombus removed; proximal thrombus should be cleared by release of the proximal clamp and great care should be taken to remove distal thrombus with fine forceps or by milking the artery from below. The tube is then inserted across the contused area and encircling ligatures placed at each end.

Postoperative Care.—All the usual precautions must be taken to increase collateral circulation; the limb must be kept exposed to avoid warmth (with the accompanying increased metabolic demand), and the remainder of the body

TABLE I—PART 1

Case No.	Date	Wound to Operation Time	Preoperative Note	Operation
1	20/9/44	9 hours	Huge perforating wound left forearm compounding both bones; hand cold, mottled and insensitive, forearm tense; general condition fair	Wounds, excised, muscle mass purple in color, median nerve divided, ulnar artery severed at bifurcation, radial intact but in spasm and occluded by a saddle thrombus; removal of this did not change the color of the hand; ulnar artery intubated and the hand became pink and warm and the muscle mass improved in color. A "captured" Germ and rug used (vetren)
2	28/10/44	9 hours	Multiple wounds of extremities; bilateral compound femurs; right foot cold, white, insensitive and immobile; general condition poor	Wounds on right leg excised and femoral artery found severed at lower end of Hunter's canal and at inguinal ligament where femur was compound; vessel ligated distally and cannulized at inguinal ligament (above profunda femoris origin). Tobruk splints to both legs, regional and general heparinization
3	29/10/44	10 hours	Penetrating flesh wound medial aspect right knee; foot cold, insensitive and immobile; general condition fair	Wound excised, femoral artery exposed as it passed into popliteal space and found to be severed, vein intact; artery cannulized, regional and general heparinization foot became pink and warm
4	15/11/44	6 hours	Penetrating wound right popliteal space; foot cool, insensitive and immobile	Wound excised and artery and vein found divided at level of head of fibula; anterior tibial not identified; either a low popliteal or high posttibial lesion; artery intubated, regional and general heparinization
5	21/11/44	5 hours	Compound fracture right wrist, huge compound left femur with cold, white, insensitive foot and absent pulsation at ankle; condition poor	Wound excision, traumatic thrombosis femoral and profunda arteries; profunda ligated, femoral intubated after removal of thrombus and foot became pink and warm with pulsation in posttibial artery; regional and general heparinization
6	26/11/44	6 hours	Large flesh wound above right knee, flesh wound of calf; absent pulsation and inability to move toes; foot warm and slight sensation present; condition fair	Wound excision and femoral artery found severed as it passed through adductor canal, cannulized but little change noted in foot although palpable pulsation in popliteal artery; regional and general heparinization
7	29/11/44	3 hours	Large perforating wound left popliteal space without fracture; cold, white, insensitive foot; bleeding requiring tourniquet; condition poor; cell volume 20%	Wound excised, low popliteal division (artery and vein) medial popliteal nerve contused; artery intubated, with foot becoming warm and pink; regional and general heparinization
8	5/12/44	4 hours	Perforating wound right knee compounding the joint; foot cold, white, insensitive and immobile with absent pulsations at ankle; condition poor	Wound excised and popliteal artery found severed immediately above anterior tibial; artery intubated; regional and general heparinization, sciatic contused but intact; foot warm and pink at conclusion of operation
9	7/12/44	6 hours	Penetrating wound left thigh, with swelling in Scarpa's triangle rapidly increasing in size, foot warm and pulsations present	Incomplete division of femoral artery probably below profunda, very little bleeding from distal artery; intubation through laceration; regional and general heparinization, foot became warm and pink
10	21/1/45	2 hours	Multiple wounds right popliteal space and calf and left forearm, no fractures, absent pulsations at ankle; foot cold, mottled, insensitive and immobile; general condition fair	Complete division of popliteal artery and vein and partial division posttibial artery; tube across complete and partial division with knee flexed; foot became warm and pink; regional and general heparinization

RESTORATION OF VASCULAR CONTINUITY

TABLE I—PART 1 (Continued)

Case No.	Date	Wound to Operation Time	Preoperative Note	Operation
11	22/1/45	3 hours	Perforating wound right thigh entrance Scarpa's triangle and exit buttock; cold, mottled foot, with absent pulsations and inability to move toes; general condition poor	Wound excised, femoral artery and vein severed and profunda vessels lacerated; femoral artery intubated and foot became warm but not pink, and patient was unable to move toes
12	21/2/45	16 hours	Large compound left knee joint with cold, white, insensitive, immobile foot; general condition good	Wound excised; traumatic thrombosis of post-tibial artery with severance of anterior tibial; thrombosed segment resected
13	1/3/45	5 hours	Huge wound compounding wrist and leaving only extensor tendon and overlying skin; hand cold, insensitive and immobile	Wound excised and radial artery ligated, ulnar artery intubated, median and ulnar nerves brought together; regional and general heparinization
14	1/3/45	6 hours	Penetrating wound right side of neck with a pulsating hematoma gradually enlarging until patient developed laryngeal distress; sensory defect left side (patient left-handed)	Right internal jugular vein and common carotid artery exposed to reveal an arteriovenous fistula; vein resected and artery intubated; regional and general heparinization
15	17/4/45	10 hours	Large penetrating wound right calf with warm foot and pulsations present	Wound excised and bleeding encountered arising from tear in popliteal artery; artery ligated and 8 hours allowed to elapse, during which time the leg became dangerously ischemic; popliteal was intubated; general and regional heparinization; foot became warm and pink; pulsations returned and patient moved toes freely

warmed to obtain maximum vasodilation. It has been our experience that elevation of the limb is of considerable importance in order to prevent "muscle edema" (see comment). Pain may be severe and should be relieved by morphine and sleep is essential. If there has been much tissue excision, bleeding is troublesome and repeated estimations of the clotting time are important; if this is above 25 minutes, bleeding will occur; if below 15 minutes, thrombosis takes place in the tube. Every effort should be made to maintain a normal blood pressure and repeated transfusions of heparinized blood may be necessary. The tube may be left in the vessel four to six days without the wall giving way at the site of the encircling ligature.

Secondary Operation.—Local anesthesia may be used and heparin should be discontinued an hour or two before operation. With artery clamps on the vessel above and below, the encircling ligatures are divided and the tube removed. The presence or absence of distal pulsation should be noted as well as the degree of ischemia; if pulsation is present or the limb is not dangerously ischemic, simple ligation may be quite safe. If one is in doubt, venous grafting may be performed immediately or it may be reasonable to wait a few hours until the ultimate outcome is certain. If secondary operation is necessary, a venous graft should be inserted, using either the nonsuture method

(Blackmore and Lord,² or the end-to-end method which has been successfully employed by Murray.³). I have found the vitallium tube method to be less tedious, but prefer the suture method, by which the full caliber of the vein is made available for the blood stream without the reduction in lumen imposed by two thicknesses of vein wall and tube, and a shorter graft may be used under just the right amount of tension. Regional and general heparinization



FIG. 5.—Case 11: This graft was removed

are necessary, and intravenous heparin solution sufficient to maintain a clotting time of 15 to 20 minutes should be continued for at least four days.

Case Reports.—Cannulization has been used in 18 cases; three of these were done without the use of heparin and in all thrombosis was almost immediate. In the remaining 15 cases the results are disappointing but not discouraging. As experience has increased, there has been a parallel improvement both in the recognition of cases requiring this operation and in the operative technic. The cases are presented in some detail and a study of the series yields much important information enabling one to approach the problem with a somewhat clearer understanding and perhaps lessen the more formidable obstacles in the path of success.

RESTORATION OF VASCULAR CONTINUITY

TABLE I—PART 2
SUMMARY OF DATA OF FIFTEEN PATIENTS UPON WHOM IMMEDIATE RESTORATION OF VASCULAR CONTINUITY AFTER ARTERIAL WOUNDS WAS UNDERTAKEN

Postoperative Course	Secondary Operation	Postoperative Course	Result
Hand remained warm and pink, he was able to extend fingers and a radial pulse felt, drug discontinued at 3 days	25/9/44: Tube removed ulnar artery ligated; further wound excision	6/10/44: Open reduction fractures with skin graft	11/7/45: Some improvement ulnar nerve supply after neurolysis, 16/6/45
Leg remained warm to calf; but foot white, cool and insensitive; some oozing from wounds, (clotting time elevated above 20 minutes)	30/10/44: Tube removed under local anesthesia and no thrombosis present; end-to-end graft using femoral vein. Blood flow through graft excellent	Heparinized 6 days, then discoumoral; leg remained warm to calf, foot dangerously ischemic; general condition on evacuation 2 weeks later, fair	Stokes-Gritti amputation, with normal blood flow through divided femoral artery
Foot remained pink and warm, edema developed and no pulsation felt; able to move toes, only slight hypoalgesia, clotting time kept elevated above 20 minutes and very little oozing from wound	31/10/44: Tube removed; no evidence of thrombosis and end-to-end graft—(femoral vein) inserted; at end of operation, foot became white and cold and a dissecting aneurysm was found at distal line; artery opened distally and a tube inserted across distal suture line, foot became warm and pink 17/11/44: The foot gradually became cooler during the last few hours and it was felt thrombosis had occurred despite heparin; wound explored and tube found to have shifted in artery, kinking it with resulting blocking of circulation; tube removed and end-to-venous graft (saphenous) used; distal suture line poor	6/11/44: Tube removed, no thrombosis noted; (general heparinization) and artery repair; heparin discontinued after 4 days, foot remained warm and pink but immobile and absent sensation	Walks 200 yards. Ischemic paralysis of sciatic nerve steadily improving. (See Figure 6)
Foot remained cool for a few hours and then suddenly became hot but I could not feel any convincing pulsation, clotting time 20 minutes		Foot never did become pink but I felt that it might survive; evacuated 5 days later	Amputation through lower third of femur, with report of infection in calf about graft

TABLE I—PART 2 (Continued)

Postoperative Course	Secondary Operation	Secondary Postoperative Course	Result
Foot became cold and white and blood pressure was difficult to keep above 100 despite blood and plasma; swelling and crepitus in thigh noted and heparin discontinued at 24 hours A few hours after operation foot became warm and pink; 8 hours postoperative, patient had a severe collapse; heparin was discontinued and a tourniquet applied to leg; whole blood given quickly, patient responded; very little oozing on dressings Good pulsation obtained in posttibial artery but general condition was poor; blood and plasma given but patient remained in <i>extremis</i> ; tourniquet applied, with no change in condition and patient died about 12 hours following operation—P.M. demonstrated death due to fat embolism Died 8 hours postoperatively despite attempts at resuscitation and tourniquet application. P. M. revealed pulmonary edema and pale kidneys; very little bleeding into the wound Postoperatively, there was considerable bleeding from the wound and the clotting time was very difficult to control; the femoral artery was ligated and heparin discontinued Foot remained warm and pink, and patient moved toes; slight oozing from wound	23/11/44: High thigh amputation for gas gangrene 29/11/44: Disarticulation through the knee joint	24 hours later patient died in an anuric state. P.M. revealed pale kidneys but nothing further Course uneventful; evacuated 7 days later	Died. (See comment) Stokes-Gritti amputation. (See comment) Died. (See comment) Died. (See comment) Died. (See comment) 14/12/44: Died due to toxemia. (See comment) Below knee amputation; 2 months later, good stump
	11/12/44: High thigh amputation for gas gangrene following ligation. 13/12/44: Metastatic gangrene right leg; disarticulation through knee 21/1/45: Tube removed sooner than usual because of its length (knee flexed), no thrombosis on removal; saphenous vein used as a nonsuture graft (see Figure 4); regional and general heparinization;	Would not respond to resuscitation; massive sulphamide and penicillin therapy Toes remained white and immobile and gradually a line of demarcation appeared in mid-tarsal region; 26/1/45: A below-knee amputation per-	

RESTORATION OF VASCULAR CONTINUITY

TABLE I—PART 2 (Continued)

Postoperative Course	Secondary Operation	Secondary Postoperative Course	Result
General condition seemed excellent but warmth only persisted to midcalf so that secondary operation was performed earlier than usual	<p>toes did not become pink but remained white, skin warm to midtarsal region</p> <p>Tube removed (no evidence of thrombosis) and the femoral vein (which had been ligated) was used as a nonsuture graft (see Figure 5). Pulsation obtained distally</p>	<p>formed; the graft examined and found patent. (See comment)</p> <p>Warmth to calf persisted but below this the foot remained cool and the toes immobile; there was no definite line of demarcation but a Stokes-Gritti amputation performed 5/2/45 and venous graft removed. It was thrombosed despite heparinization</p>	<p>Stokes-Gritti amputation</p>
General condition remained satisfactory but foot remained dead in appearance	<p>22/2/45: 24 hours later the posterior tibial artery was intubated and the skin became pink and warm but the foot remained immobile and insensitive</p>	<p>Due to inaccurate clotting time, thrombosis took place in tube and Stokes-Gritti amputation performed 24/2/45</p>	<p>Stokes-Gritti amputation</p>
24 hours later, fingers pink and warm and patient able to extend fingers; 48 hours later, clotting time dropped to 13 minutes and hand became cold and painful	<p>6/3/45: Amputation through lower third of forearm</p>		<p>Amputation through forearm</p>
8 hours later patient developed laryngeal distress due to oozing in wound (clotting time 38 minutes)	<p>Tracheotomy performed; tube removed and artery ligated</p>	<p>Transient complete hemiplegia gradually improving</p>	<p>5 months later, sensory defect left hand and slight limp</p>
Foot remained warm and pink, and tube left in place 4 days	<p>Tube removed (no thrombosis) and vessels clamped; pulsations disappeared and foot became cold and white; secondary venous graft (suture method) performed with return of pulsations and warm, pink foot</p>	<p>Heparin continued for 4 days; and foot appeared normal with good movement of toes and pulsation in both arteries</p>	<p>2 months later, patient seen walking with slight limp. (See Figure 7)</p>

COMMENT

Blood Loss.—When an artery is divided, particularly if the division is incomplete, bleeding either into the tissues or to the exterior is considerable; as a protective mechanism, peripheral vasospasm results and in this way the limb may become dangerously ischemic if the blood volume is not quickly restored. To Major J. Dacie and Captain J. Homer the author is indebted for hematocrit readings and blood volume studies on a few of these cases which enable one to make some interesting observations. The estimation of the



FIG. 6.—Case 3: Dotted line represents gradually recovering sensation

hemoglobin is, of course, misleading, since one is dealing with total blood loss, and we have noted that a hemoglobin of 70 to 80% within a few hours of wounding drops to 40 to 50% when the blood volume is restored with fluid other than whole blood (Fig. 2). In Case 8 the patient had lost 80% of his total blood volume prior to operation and recovery could hardly be expected. It is obvious that large amounts of whole blood must be given to increase the supply of oxygen to the ischemic tissue (Fig. 3), and that postoperative bleeding assumes great importance since the loss of 500 cc. in an already exsanguinated patient may prove fatal.

Heparinization.—This has been our greatest problem, and the difficulty of administering this drug at a regular rate under Front Line conditions is indeed real. Inaccurate clotting times and irregular rate of flow make the path between thrombosis and bleeding a narrow one and difficult to follow. Pressure dressings impede the collateral circulation, and it is unwise to close the wound tightly. It is dangerous when multiple wounds are present, and if one delays heparin postoperatively to allow clotting to take place in the wounds, thrombosis occurs in the tube. This is a difficult but not insurmountable problem.

Wound Excision.—If one has to choose between heparinization or radical excision of a wound then there should be no doubt from the lesson learned in Cases 5 and 9, in which excision was minimized in view of the effects of sub-



FIG 7.—Case 15: Photograph taken in a German prison camp, two months after operation.

sequent heparinization. The wound must first be completely excised before one considers the use of heparin. Fibrin foam has been used on one occasion and it would be advantageous to have a thrombin preparation for local application.

Revitalization.—The effects of flooding the circulation with the metabolites of ischemic muscle raises a controversial question. Operations upon the extremities under tourniquet do not as a rule cause systemic effects on the release of the tourniquet; in a limb which had been kept at room temperature for 24 hours no untoward systemic effects were noted (Case 17), nor were any ill effects noted in the autograft of the hand in Case 13. In Case 6, two bottles of whole blood administered simultaneously with the application of the tourni-

quet might have been the deciding factor in resuscitation. The phenomenon of fat embolism (Case 4) in the absence of fracture is little understood.

Sympathetic Block or Ganglionectomy.—We have felt that if restoration of the continuity of the main vessel in the dangerously ischemic limb fails to provide skin, muscle and nerve with enough arterial blood for survival then the fate of the limb will not be altered by sympathetic denervation.

Rigid Tube or Graft.—The blood flow in the extremity is much greater through a tube than through a venous graft. This is particularly true if the gap is long. In Case 10, a patent venous graft (examined two weeks after insertion) carried only enough blood to maintain viable skin, while with the longer tube in place the patient had moved the toes (Fig. 4). The passive dilatation of the vein wall, however slight, has the effect of lessening the force of the arterial stream; this effect increases with the length of the graft.

Muscle Edema.—Every surgeon amputating an ischemic limb has noted that the skin may be warm (even hot) in the calf, although the muscle beneath is ischemic. The muscle is hard, swollen, and pale; it does not contract or bleed and yet bleeding in the subcutaneous tissues may be brisk. Microscopic examination shows considerable separation of the muscle bundles and each fiber is swollen and pale. Muscle demands a greater amount of blood than skin and the presence of any edema within the muscle may create enough tension to prevent blood entering unless it does so with considerable force. This explains the failure in Case 10, and might explain the occasional success of the fascia-splitting operation in the ischemic limb with intact vessel. In Case 10, bleeding was brisk on incision of the subcutaneous tissue of the calf; the muscle beneath was pale, edematous, and it did not bleed; yet when the posterior tibial artery was divided there was a good flow of blood; however, this was a constant stream and not pulsatile as a result of the length and type of graft (Fig. 4).

Autograft.—In the upper extremity, whatever the function of a viable hand, it may be preferred to an artificial one. In Case 13, at the end of 48 hours the fingers were warm and the patient could extend them, but on the fourth day thrombosis occurred due to faulty heparinization and the hand was amputated.

SUMMARY

In the dangerously ischemic limb, reestablishment of the circulation by artificial anastomosis is practical under conditions where heparinization is possible. The technic of the operation is simple, but postoperative care difficult. The operation has been performed 15 times using heparin; thrombosis does not occur in the tube if the clotting time is kept sufficiently elevated. Careful administration of this anticoagulant with repeated estimations of the clotting time are necessary to ensure success. During the critical period, blood loss must be carefully considered, and the blood pressure maintained by repeated transfusions of whole blood. The limb must be elevated to prevent "muscle edema"; warming the limb is to be avoided and care must be taken with dress-

ings. The tube may be left safely in the vessel up to six days. The second stage of venous graft has been performed six times, the nonsuture method twice, and the suture method four times. Other factors being equal, the success of the graft is in inverse proportion to its length. Following venous transplant, heparinization should be continued for at least four days.

CONCLUSION

A rigid tube is preferable to a venous graft as a temporary arterial bridge in acute ischemia of the limb. The results of this type of anastomosis have not been impressive and success has been a feat in war surgery in the Forward Area. It is, however, only a beginning in a new field and the application to elective arterial surgery may be of some importance.

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RECONSTRUCTION OF THE THUMB*

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IN EVALUATING hand injuries, destruction of a thumb is considered to be equivalent to the loss of one-half a hand. To the average individual who must gain his livelihood manually, this injury constitutes a serious handicap.

During a period extending over two years, we have had the opportunity of seeing 26 cases on our service who had a loss of sufficient length of thumb that some type of reconstruction of the digit was considered in order to restore the man's usefulness in a peace-time occupation. Of this group of 26 cases, nine were transferred to other Naval Hospitals for treatment. Out of the remaining 17, three refused operation because they did not feel that their peace-time activities would be hampered too seriously by the deformity. One case lost the entire thumb and its corresponding trapezium, which we felt was too extensive an injury to warrant any type of practical reconstruction. This patient was fitted with a prosthesis, thus, adding some improvement to the efficiency of his hand. The remaining 13 cases requested surgical reconstruction and our experience with this group constitutes the essential theme of this presentation.

METHODS OF RECONSTRUCTION

In the greater majority of instances, our chief aim has been to establish the opposing mechanism of the thumb against the remaining fingers. The reconstruction of all phalangeal movements, while a desirable ideal, is naturally beyond the scope of practical endeavor in the average replacement. However, four methods of physiologic restoration must be considered: 1. Deepening the thumb web. 2. Pollicization of a remaining partial finger. 3. Replacement with a toe. 4. Lengthening the existing thumb stump.

The operation for deepening the existing web between the thumb stump and the metacarpal of the index finger is the quickest and simplest procedure, and was undertaken on three of our cases. A modified syndactylism operation was carried out plus detachment of the small muscles of the thumb and the first metacarpal. This procedure, of course, gives no length to the thumb, so that the power of opposition is not improved. The chief benefit derived is greater ability to hold an object or tool between the thumb and medial side of the hand.

The second procedure, pollicization of the index finger has been described meticulously by Bunnell,¹ and Gillies and Cuthbert.² However, the method should be limited to those cases that present a simultaneous subtotal loss of

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The opinions and views set forth in this article are those of the writer and are not to be considered as reflecting the policies of the Navy Department.

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the index finger. Since the thumb is shorter than the index, one can utilize the shortened first finger to advantage. The deliberate partial amputation of a normal index finger to reduce it to a desirable length for a thumb should never be considered. If such a finger were lost during the transfer procedures, further serious damage to the injured hand would result. This complication need not be looked upon with the same degree of seriousness if an already damaged index finger were accidentally lost during some unforeseen operative complication. However, it must be pointed out, that where the indications exist, this reconstructive procedure has considerable merit. We have had no cases in which we felt this operation was indicated.

The third method is that described by Nicoladoni.³ This operation consists in transplanting a toe (other than the great toe which must not be sacrificed deliberately because of impairing the balance of the foot) to replace the thumb. The toe with its tendons and phalanges are transplanted *in toto* to the thumb by means of a pedicle flap attachment of the toe base to the thumb stump. The procedure, while theoretically possible, can be executed only by prolonged attachment of the hand and foot until a new blood supply is established. Needless to say the position is very irksome to the patient, sufficiently so that we have never had the desire to utilize this operation. One of the former members⁴ of our Service, however, states that he did this operation successfully in a small child who had a congenital absence of the thumb. It must be added that children tolerate awkward positions better than adults.

The fourth method is the one with which we have had the greatest experience. Ten thumbs of this series have been reconstructed by this operation.

The procedure consists in constructing first a tube-pedicle flap of skin and subcutaneous fat from a hairless area in the flank. The tube should be made long enough so that there will be adequate mobility of the upper extremity when it is attached to the thumb stump. For longer reconstructions, we have made the customary tube pedicle, leaving both ends attached to the donor area until adequate circulation becomes established in the flap (Fig. 1). Later, the distal end of the tube was attached to the thumb stump. In cases where a shorter flap was needed, a simple flat flap was elevated, leaving only the base attached for blood supply. This flap was then sutured into a tube (Fig. 2-A) at once, and the open end attached to the thumb base at the same operation. In either event, the new union is permitted to grow for three to four weeks before detaching the abdominal origin of the tube. During the interval, however, the blood supply into the new thumb attachment was hastened by either "delaying" the proximal end (Fig. 3-B) of the flap, or by simply clamping it off at intervals with a rubber band. Finally, when one is certain that the new attachment of the tube pedicle will nourish the entire flap, the opposite end is divided from its point of origin and the end sutured over for closure. It should be added, that a tube pedicle of ample length should be provided, since any excess can always be trimmed off at the final revision. Also, after severing the abdominal attachment, the tube should be supported with a splint to prevent angulation and circulatory obstruction at its base.

STABILIZATION

After the flap has healed completely and become well softened, it must then be stabilized to the base of the thumb by some type of support. Various structures have been utilized by different operators for this purpose. Costal cartilage has been unsatisfactory. It has been the experience of most surgeons that the



FIG. 1.—This patient suffered not only a loss of his thumb, but also the index finger. The stump of the first metacarpal was covered with a thin, tender scar which extended upward over the medial side of the midfinger, producing an obvious contracture. In designing the flap to construct this thumb, an extension was made from the medial end of the tube-pedicle to cover over the middle and index finger stump to replace the scarring.

use of bone grafts from the tibia or iliac crest gave rise to an unpredictable amount of absorption when used for this purpose. In searching for a better substitute, it was suggested by Hudack,⁵ from our Orthopedic Service, that the twelfth rib be tried. This source was adopted in the first case of our series and has been so satisfactory that it was used in each of the others that followed.

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FIG. 2-A

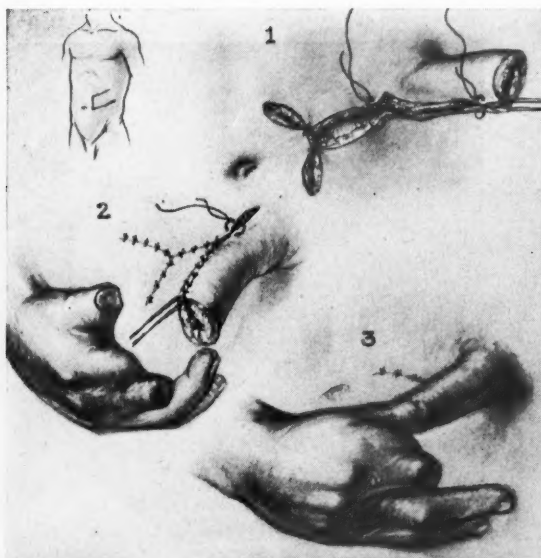


FIG. 2-B



FIG. 2-C



FIG. 2-D

FIG. 2.—(A) Since a new thumb of lesser length was needed here, a direct flap with good blood supply was elevated and detached completely except for its base, at the first operation. The flap was tubed and sutured to the thumb stump at once. This procedure is useful when shorter skin flaps can be utilized, since it saves time. It must be pointed out, however, that it takes experience and judgment in dealing with skin flaps before one can evaluate the risk involved in taking this short cut. (B) shows the patient's hand, and (C) and (D) the result obtained. This patient plans to return to farming, which he states will include milking cows.

FIG. 3-A

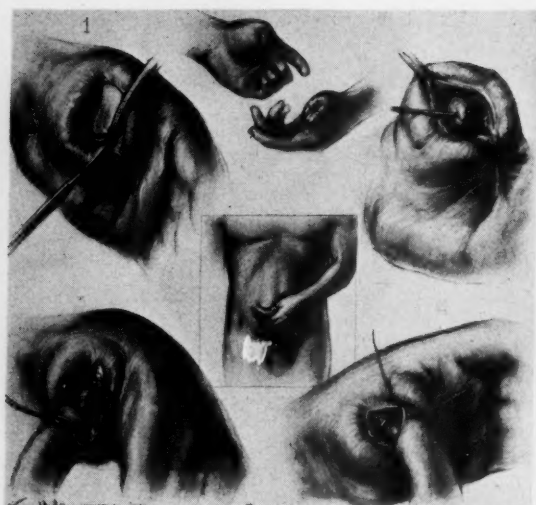


FIG. 3-B



FIG. 3-C



FIG. 3-D

FIG. 3.—(A) This shows a drawing of the pedicle after detachment of its distal end from the abdomen. The scar is excised from the thumb stump and the open end of the tube suture into the defect over the metacarpal. (B) Illustrates the tube attached and subsequent "delay" or partial separation of the flap from the abdomen ten days prior to complete division. "Delaying" the flap hastens establishment of adequate circulation at the thumb attachment. (C) Demonstrates reopening the base of the pedicle after the distal end is well-healed and softened. The metacarpal stump is exposed subperiosteally and the bone graft taken from the left 12th rib. After shaping the graft, the metacarpal stump is drilled and the dowled end of the bone graft swedged into it after first placing the opposite end into the distal portion of the tube. Note the small drill holes placed through the bone graft to encourage early vascularization. The skin incision is then closed and the new thumb supported until bony union occurs. (D) Shows the preoperative view of this case.

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Exposure of the twelfth rib is obtained by an incision directly over it. Any of the underlying muscles that cannot be retracted medially are divided. The rib is exposed and removed subperiosteally (Fig. 4-A), following which the wound is closed by layers.



FIG. 3-E



FIG. 3-F

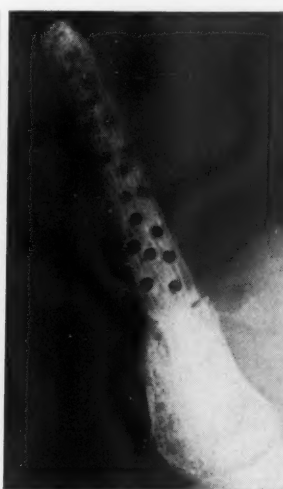


FIG. 3-G

FIG. 3.—(E) and (F) show the final result of this case. (G) Illustrates an early roentgenographic appearance of the bone graft.

The rib graft is then shaped so as to form a peg in its proximal end (Fig. 3-C). Several small holes are drilled through the bone to encourage more rapid vascularization of its substance.

In one case (Fig. 4-A), we next placed the bone graft into a small tunnel of the tube pedicle while it was still attached to the abdomen. Later, when the pedicle was transferred to the thumb stump, the peg end of the bone graft (Fig. 4-B) was swedged into the base of the remnant of the first metacarpal. However, it seemed too precarious to keep the bone graft in position while the skin flap was healing. Therefore, in the other nine cases we transplanted the bone graft directly into the healed tube after it was well-vascularized to the thumb stump. The technic (Fig. 3-C) consists of exposing the end of the metacarpal through an incision at the base of the pedicle attachment. Retracting the tube to one side, a hole is drilled into the medullary cavity of the metacarpal. A pocket is next made into the center of the tube by blunt dissection with scissors, going from the proximal end toward the distal, but being careful not to traumatize or open the tip. The end of the bone graft is next placed distally into the tube pocket, following which the peg on the proximal end is pushed into the previously-drilled metacarpal hole. The graft remains secure by friction and no other fixation is necessary. The skin incision is next sutured and the reconstructed thumb supported with either a splint or plaster of paris encasement.

FIG. 4-B

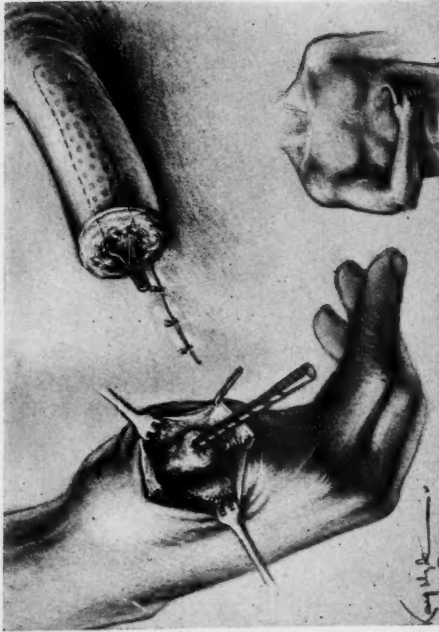


FIG. 4-A

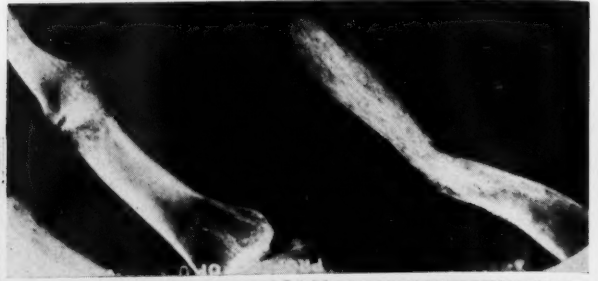
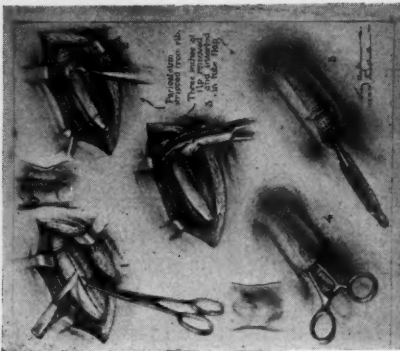


FIG. 4-E



FIG. 4-D



FIG. 4-C

After placement of the bone graft, it has been observed that clinical union occurs in two to three months and roentgenographic evidence of complete healing is seen in six months. After clinical union takes place, the thumb is finally trimmed of any excess skin and subcutaneous fat. Occasionally, it has been necessary to trim off some of the bone graft tip to give a more desirable length. When this was done, it has been gratifying to observe the profuse bleeding that came from the cut end of the transplanted bone. Except for bathing, we have kept these newly constructed thumbs supported with an aluminum splint until evidence of complete bony union was visualized (Fig. 4-E).

COMPLICATIONS

Three types of complications were encountered in our series of ten cases. The most persistent was noted in eight. This consisted in a break-down of the end of the tube pedicle flap after it had been divided from its abdominal origin, and is a complication that has been encountered by other plastic surgeons, both in this country and abroad.^{6, 7} In each case, at the time of sectioning the tube, an excellent blood supply was noted. After closing the open end by suture, primary healing always occurred. But 10 to 18 days later, a cyanosis and subsequent gangrene developed along the suture line and then spread out over the tip. It seemed at first that this was probably due to passive congestion, but pressure dressings over the tip did not produce material change in any case. Following the necrotic process, an ulcer developed over the tip that would not heal primarily nor would a thin split-skin graft grow on the granulating base. Chemotherapy was of no aid. Ultimately, the ulcer was excised and the flap end resutured. In some cases the process repeated itself two or three times before permanent primary healing occurred.

The second complication was that of infection and necrosis of the bone graft. This occurred in two cases. In each, the graft was removed when it was evident that sequestration was inevitable. After permitting the tube pedicle to heal, the opposite twelfth rib was transplanted and grew successfully. Consequently, we feel that this complication was probably due to a technical error at the time of carrying out the primary bone graft.

The third complication was entirely accidental. This patient played water basket-ball against instructions three months after his bone graft had been

FIG. 4.—(A) Explains the operative technic for removing the 12th rib. In this case the bone graft was placed first into the tube pedicle while it was still attached to the abdomen at each end. Later, (B), the distal end of the tube was attached to the thumb stump and at the same time the base of the bone graft swedged into the metacarpal. This order of procedure has been abolished because of the difficulty in holding the hand in position without accidentally pulling the bone graft out from its new bed. The procedure described under Figure 3 is simpler and associated with less hazard.

Figures 4-C and 4-D illustrate the case involved. Figure 4-E shows the roentgenogram of the bone graft 16 months after transplantation. Good bony union is noted. (This is the same case that suffered a greenstick fracture at the base three months before, when injured while playing water basket-ball.) This patient plans to return to a civil occupation as a mathematics instructor in a University. We feel confident that the restoration will enable him to hold a piece of chalk.

performed. During this athletic escapade, the tip of the new thumb was accidentally struck with the basket-ball, producing a greenstick fracture near its base. The fracture was reduced and splinted, and it was very gratifying to note that complete union of the bone graft occurred in approximately two months.

FIG. 5-A

FIG. 5-B

FIG. 5-C

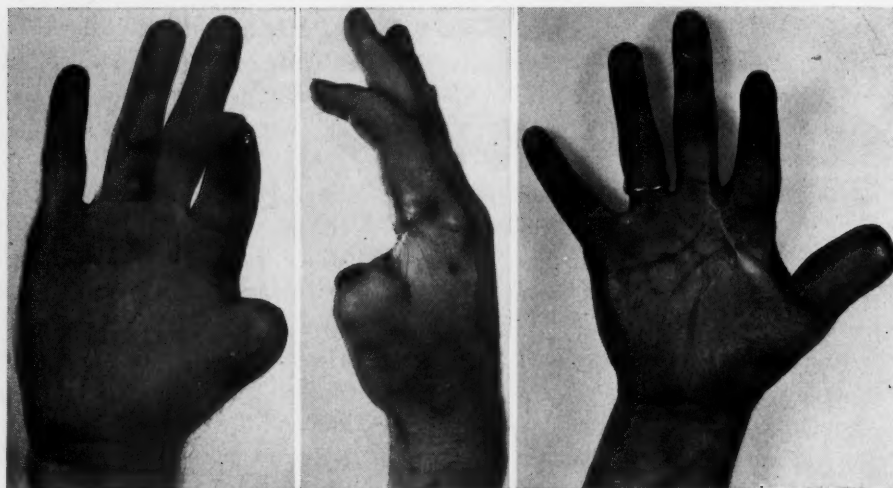


FIG. 5-D

FIG. 5-E

FIG. 5.—(A) and (B) Show a partial loss of the thumb complicated by a healed compound fracture of the index finger. This latter injury limited complete flexion of this digit very markedly. The thumb was reconstructed by the "short method" described in Figure 2. The result is shown in Figures (C) and (D). Figure (E) shows the bone graft three months after transplantation.

SUMMARY

In a series of ten cases of reconstruction of the thumb, utilization of the twelfth rib for stabilization has given very satisfactory results in our hands.

RECONSTRUCTION OF THUMB

FIG. 6-A



FIG. 6-B

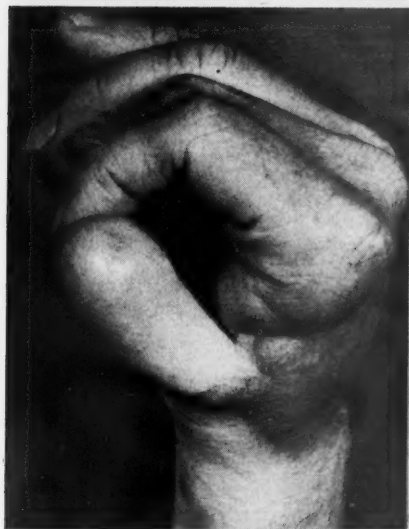


FIG. 6-C



FIG. 6-D

FIG. 6.—(A) This case is included because of the extensive loss. (D) Shows the roentgenogram of this patient, demonstrating a complete absence of the metacarpal down to the trapezium (greater multangular). A new digit was constructed, Figs. (B) and (C), with a good result considering the magnitude of the deformity. The roentgenogram (D), taken four months after transfer, shows how the base of the bone graft was swedged into the trapezium. Some motion was obtained from the residue of the small muscle group at the base of the thumb. This is an ideal case in which to consider pollicization of the index finger if a coexisting partial amputation of the index occurs simultaneously. However, it does not seem good judgment to hazard transfer of an uninjured index finger. (See text.)

While this method of restoration does not provide phalangeal joint activity, there is sufficient range of motion at the metacarpocarpal point to allow for good opposition against the other remaining fingers. This simple action does much to restore the usefulness of the hand.

All types of sensation except that of stereognosis develop in the transplanted skin flap. The speed with which these sensory recoveries develop followed no definite rate. The time varied with different individuals from six months, to one case which still does not have complete return after two years.

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CERVICAL RIB: THE ROLE OF THE CLAVICLE IN OCCLUSION OF THE SUBCLAVIAN ARTERY

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THIS REPORT includes the study of a series of cases of cervical rib in which it was found that the subclavian artery was intermittently occluded by mechanical pressure between the clavicle and the aberrant rib. In one of these cases, the vascular disturbances were sufficiently severe to lead to gangrene of three digits of the right hand. Scalenotomy alone failed to relieve the condition which was corrected only by excision of the offending rib.

Jones⁷ pointed out that while snakes have cervical and lumbar ribs, lizards do not. His theory is essentially that the outgrowth of mesenchymal and neurogenic structures to the limb buds shear off the soft uncalcified anlagen of the neck ribs during embryologic development. If the upper extremity descends too fast and too far, it shears off the upper thoracic ribs as well (Fig. 8). If it descends too slowly, the seventh cervical rib is permitted to develop. The roentgenographic findings in two of our cases tend to confirm Jones's theory. Figure 7 shows a deep indentation made in the cervical rib by the subclavian artery. The impression one gets is that during the embryonic life of this individual the shoulder descent stopped as the neurovascular structures were cutting through this rib anlage. The same general principle applies to the aberrant first thoracic rib in Figure 8, except that in this case the neurovascular structures had proceeded caudad too far and were in the process of shearing off the highest thoracic rib when the descent was halted. The head of this rib had been levered cephalad from the pressure on its distal end.

Jones believed that vascular symptoms result from irritation of the sympathetic nerve fibers in the lowest trunk of the brachial plexus. Todd¹³ produced further evidence to support this theory which was later elaborated upon by Telford,¹² who believed that only those cases of cervical rib that have some abnormality in the distribution of sympathetic fibers have symptoms. He has shown that in the normal individual these sympathetic fibers to the blood vessels join the roots of the brachial plexus and are mixed thoroughly with the myelinated nerve fibers by the time these nerve trunks cross the cervical rib. In approximately one individual in eight, the sympathetic nerve fibers to the blood vessels form a special bundle situated just below the lowest trunk of the brachial plexus. This bundle of unmyelinated nerve fibers is in a position to be irritated by an abnormal cervical rib since it crosses the rib as an entity before its fibers mingle with those of the larger nerve trunks. It is in this type of case

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that the vascular symptoms are believed to occur. Telford¹² does not believe that gangrene could be caused by pressure on the artery alone. He has demonstrated that occlusion of the main artery to the arm, when it occurs, begins beyond the lower border of the major pectoral muscle. It is at this site that the sympathetic nerve fibers surrounding the blood vessel itself come to an end and the unmyelinated nerve fibers from the brachial plexus previously referred to begin to take over. Irritation to these sympathetic fibers would set up a spasm in the blood vessels. Such vascular disturbance may be brought about by irritation of the sympathetic fibers from friction or pressure.

Factors which lead to abnormally intimate relationship of the brachial plexus and cervical or first rib are: (1) anatomic position of the lower nerve trunk and rib as previously described; and (2) abnormally rapid descent of the shoulder girdle from either developmental causes, abnormal weight-bearing, or from weak muscles. If depression of the shoulder is great, the sympathetic nerve fibers may be completely destroyed and no vascular spasm will result. Telford¹² sets forth an interesting theory to explain the thrombosis occurring in such cases. It is his belief that the spasm set up interferes with the vasa vasorum. The nutrition of the endothelium is thereby disturbed leading to thrombosis.

Blair³ also believes that the vascular symptoms in patients with cervical ribs are produced by vasospasm. He studied a case of cervical rib with vascular symptoms who subsequently died. Microscopic examination of the lowest root of the brachial plexus revealed a distinct bundle of unmyelinated sympathetic fibers situated at a low level in direct contact with the aberrant rib. He believed that stimulation of these sympathetic fibers by friction over the cervical rib had produced the vascular disturbances.

Adson and Coffey¹ focused attention on the scalenus anticus muscle as an important factor in production of symptoms in cases with cervical rib. They believed that a great deal of the disturbance produced was due to pressure exerted on the subclavian artery and brachial plexus by the scalenus anticus muscle in front and by the cervical rib from behind. They introduced a diagnostic maneuver which determines the degree of scalenus anticus pressure. This test, now known as the "Adson maneuver," consists of putting the scalenus anticus muscle under tension by having the patient turn the head toward the affected side, throw the head back, and take a deep breath. The test is positive if the radial pulse is diminished or shut off. They recommended section of the scalenus anticus muscle with or without removal of the cervical rib for correction of this condition.

Ochsner, Gage and DeBailey⁹ further incriminated the scalenus anticus muscle by showing that it could do harm to the brachial plexus even in the absence of a cervical rib. One of the theories they offer to explain the mechanism whereby symptoms are produced is essentially that of Todd, previously referred to. This theory is based on the fact that the thoracic cage and shoulder girdle descend to a lower level as one grows older. This drop is brought about by two factors; the pull of gravity; and the tension of the rectus abdom-

inis muscle. If the descent of the thoracic cage is held up for some reason and the shoulder girdle continues to drop, the nerves and arteries to the arm become unduly stretched over a cervical rib or a high first rib. When the lower roots of the brachial plexus become irritated by a cervical or high first rib spasm of the scalene muscle results, elevating the offending rib further, and so a vicious cycle is set up.

They reported six cases of scalenus anticus syndrome, all women. Four had symptoms on the right and two on the left, and all had tenderness on pressure over the scalenus anticus muscle. The diagnosis was worked out on a scientific basis. This syndrome must be differentiated from: (1) supraspinatus injury; (2) subarachnoid tumor; (3) cervicodorsal sympathalgia; and (4) Raynaud's disease. To this list may be added cervical arthritis; brachial plexus neuritis; and a slipped intervertebral cervical disk. They have obtained good results in such cases by resection and removal of a portion of the scalenus anticus muscle close to its attachment to the first rib.

Hansson⁶ suggested a series of exercise for relief of symptoms. The aim of these exercises is to strengthen the trapezius and levator scapulae group of muscles in order to elevate the shoulder girdle. We have found these exercises beneficial in cases of cervical rib with minimal symptoms.

Craig and Knepper⁴ recommended removal of a portion of the cervical rib, as well as section of the scalenus anticus. Patterson¹⁰ divides the scalenus anticus and, in addition, the scalenus medius and removes a portion of the cervical rib.

Judovich⁸ mentions that a narrowing of the costoclavicular space may produce symptoms from vascular compression. Wright¹⁵ believes that the large nerves and blood vessels to the arm may become pinched at times between the first rib and clavicle. Aynesworth² also lists the possibility of obstruction of the subclavian artery between the clavicle and a cervical or first rib. He also believes that trauma to the subclavian artery may result from excessive movement of the shoulder.

MECHANICS

Cervical rib occurs more frequently on the left, but symptoms are usually on the right because of the greater use of the right arm. Similar symptoms may be produced when no cervical rib is present. Symptoms are usually a result of injury to the subclavian artery or the brachial plexus nerves. Injury to these structures may be produced as a result of either (1) pressure; (2) stretching; or (3) friction. Pressure symptoms are produced from a pinching between two structures, one behind and one in front. The structures producing pressure from the back may be: (1) cervical rib; (2) a fibrous band representing a cervical rib; or (3) scalenus medius and posticus muscles. The pressure from in front may be from the scalenus anticus muscle or the clavicle.

Stretching of the nerves and arteries are produced by a cervical rib or a highly placed first rib which acts as a pulley over which these structures run. Tension may be increased distally by a depression of the shoulder; proximally

by a low origin of the roots of the brachial plexus. Tension from a high first rib or cervical rib may be accentuated by an elevation of the thoracic cage in general as a result of excessive muscular development resulting from strenuous exercises. The strain of military life involves the use of the extraordinary muscles of respiration, particularly the sternomastoid and the scalene muscles, resulting in an elevation of the thoracic cage.

Ochsner⁹ believes that the first rib may be elevated by spasm of the scalene muscles associated with either myositis or brachial plexus neuritis. Depression of the shoulder is an important factor in females and older males with weakness of the musculature. It may also be present in younger men from excessive weight-bearing, such as carrying a pack or from faulty development.

SURGICAL ANATOMY

The surgical anatomy of cervical rib is essentially that of the posterior triangle of the neck. The posterior triangle curves obliquely around the lateral aspect of the neck. It is bound in front by the sternomastoid, behind by the trapezius, while its base is formed by the middle third of the clavicle. Its floor is formed from above downward by the splenius capitis, levator scapulae, scalenus medius, and posticus muscles, the first rib and the first digitation of the serratus magnus. The scalenus anticus muscle does not form a part of the posterior triangle since it is directly behind the clavicular portion of the sternomastoid muscle. The contents of the posterior triangle are: (1) arteries—the third part of the subclavian above which is the transverse cervical and suprascapular; (2) veins—the subclavian and external jugular; and (3) nerves—the brachial plexus.

The third part of the subclavian artery lies in the base of the posterior triangle about which is the suprascapular and transverse cervical arteries. Above these again is the omohyoid muscle. The subclavian artery is divided into three parts by the scalenus anticus muscle. The first part is medial to the muscle, the second part directly behind, and the third part is lateral. The subclavian vein is below and in front of its artery with the scalenus anticus muscle lying between. The phrenic nerve passes downward in front of the scalenus anticus muscle toward the medial border. The cervical pleura is directly below and behind the first and second parts of the subclavian artery. It extends higher in the neck in the case of persons with cervical rib.¹⁰ An important relationship to the first part of the subclavian artery on the left side is the thoracic duct which arches down in front of it in order to end at the junction of the internal jugular and subclavian veins. The first rib is below the third part of the subclavian artery, while the external jugular vein crosses in front. Posteriorly, it is in relation to the median and posterior scalene muscles with the lowest trunk of the brachial plexus intervening.

A medially placed cervical rib may be directly behind the scalenus anticus muscle with the large nerves and arteries intervening. This type of case would give a positive Adson test and would be expected to be relieved by a scalenotomy alone. A laterally placed cervical rib behind the third portion of the

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subclavian artery would be more liable to produce symptoms from pressure on the subclavian artery between the abnormal rib and the clavicle. Such a case would show reduction or absence of radial pulse in the attention position and would require removal of the cervical rib in addition to scaleniotomy.

CLINICAL ASPECTS

Symptoms occur in two general types: (1) young muscular males; and (2) older debilitated males or females. Only 55 per cent of cervical ribs give symptoms and only about 11 per cent require surgery.

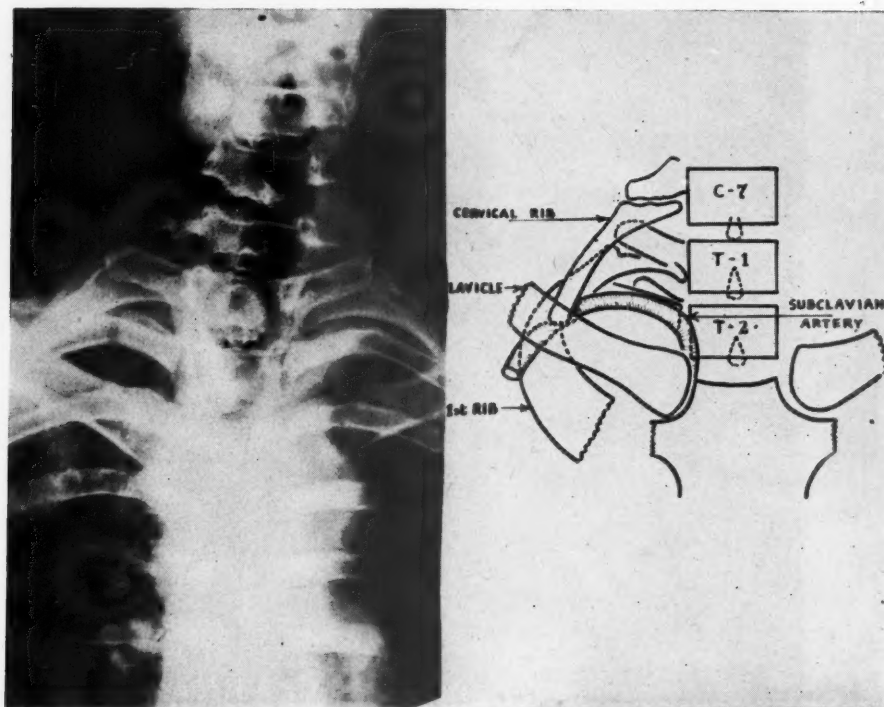


FIG. 1.—This illustrates the manner in which the subclavian artery was occluded between the cervical rib and clavicle. This rib produced vascular symptoms only. (Case 1.)

Symptoms are either (1) neurologic or (2) vascular. Neurologic symptoms may be due to pressure, stretching, or friction. Neurologic pain is of a sharp lancinating or boring type. It may be located in the scapular region with radiation down the arm and at times up the side of the neck. Pain is worse toward the end of the day, especially in females, and is aggravated by certain types of work which depresses the shoulder, such as weight-bearing or sweeping. One of our patients developed symptoms when he was painting low shelves; swinging the arms in marching caused symptoms in the same man. Anesthesia, paresthesia, formication, burning, tingling, or numbness may be present. Physical examination may reveal atrophy of muscles supplied by the ulnar nerve, and occasionally those supplied by the median. Trophic disturb-

ance may be present, such as dryness of the skin, loss of hair, loss of nails, but actual gangrene is rarely found.

Circulatory symptoms include blanching, numbness, tingling, or coldness. These occur during the carrying of a pack or gun, assuming the position of attention for long periods or while asleep. One case developed symptoms while sitting in a picture show.

The chief *diagnostic* problem is to determine whether or not a cervical rib known to exist, roentgenographically, is responsible for presenting symptoms.

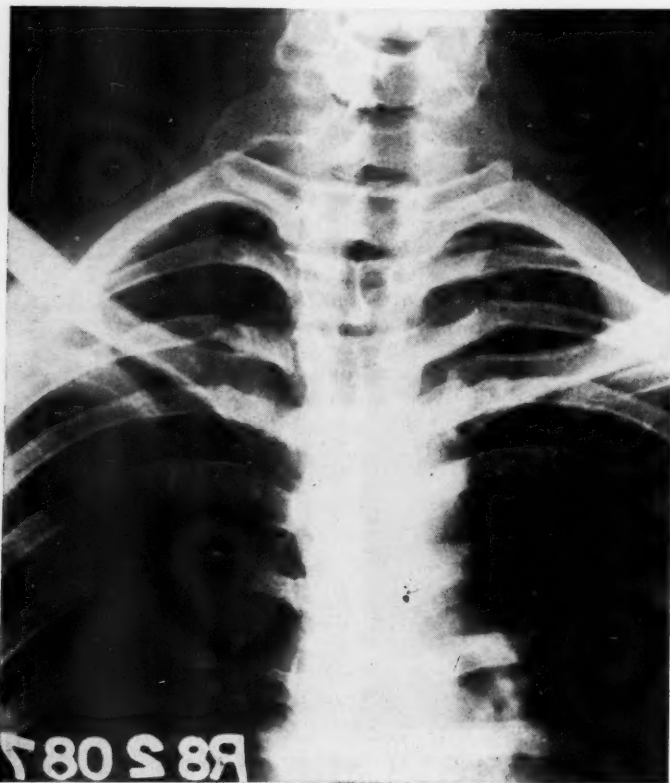


FIG. 2.—After removal of the greater part of the offending rib.
(Case I.)

A history of scapular pain radiating down the arm, worse on depression of the shoulder, is a good indication of neurologic pressure. Several tests have been worked out which are helpful in determining nature and degree of disturbance. One of these, the "Adson maneuver," previously referred to, supposedly puts the scalenus anticus muscle under tension, resulting in pressure on the subclavian artery and brachial plexus nerves. The test is positive when the pulse is shut off or reduced in volume, as determined by palpation, blood pressure or oscillometric readings.

In the cases herewith presented it was found that with laterally placed ribs the pulse may be obliterated by counter pressure from the clavicle when the

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shoulders are thrown back, as in the position of attention. In such cases, the cervical rib can often be felt in the base of the posterior triangle of the neck. The subclavian artery may be palpated in front of this and the clavicle in front of this again. If the patient is then asked to throw the shoulders back, the artery may be occluded at this point. Under such circumstances one can feel the subclavian artery pulsate distal to the scalenus anticus muscle, and so incriminate the clavicle as the subject of counter pressure.

The *treatment* may be medical or surgical. Medical treatment, which aims at elevation of the shoulder girdle by exercises designed to strengthen the

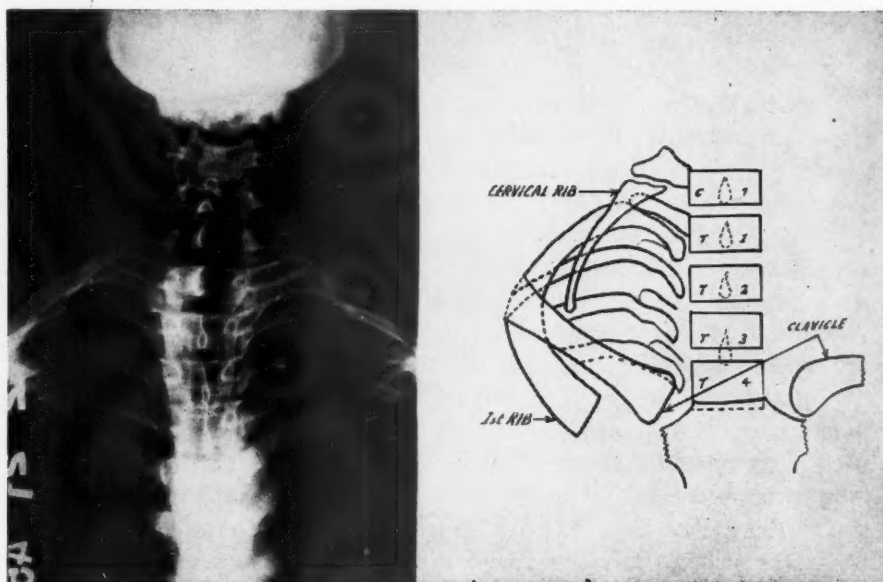


FIG. 3.—Symptoms in this case were neurologic and vascular. The lower trunks of the brachial plexus were stretched over the sharp upper margin of this narrow rib. The subclavian artery was occluded between the slightly expanded tip and the clavicle. (Case 2.)

trapezius and levator scapulae muscles, may be tried in mild cases. One exercise recommended by Hansson⁶ consists of clasping the two hands together and pulling straight back at the same time as the shoulders are elevated. The patient is taught not to throw the shoulders back or to carry heavy weights. Posture should be that which is considered as good posture in general, except that the chin should not be pulled in but allowed to go forward and slightly elevated to relax the scalene muscles. The shoulders may be squared-off but should not be thrown back. If symptoms tend to develop at night, the patient should be taught to lie on his side with both shoulders forward, or if he lies on his back, he should have an extra pillow under the affected shoulder and the head flexed forward. The soldier is usually placed on duty, with carrying of heavy packs forbidden; also the strenuous exercises should not be indulged in since the muscles of extraordinary respiration tend to elevate the thoracic cage.

Surgical treatment consists of division of the scalenus anticus muscle with or without removal of the surgical rib. The aim of the treatment should be the relief of pressure or tension on the arteries and nerves. This is accomplished by cutting the scalenus anticus muscle to allow the subclavian artery and large nerves to fall forward and to a lower level. If there is still tension, then the cervical rib must be removed. Ochsner⁹ believes that division of the scalene muscle permits the first rib to drop to a lower level. This drop, however, is probably hindered by attachments of other muscles, such as the scalenus medius and posticus to the first rib and also the fact that the first rib is fixed to the sternum which, in turn, is held up by the sternocleidomastoid.

SURGICAL TECHNIC

Besides the brachial plexus and the subclavian artery, there are three other important structures to guard against injuring. They are: (1) the phrenic nerve; (2) the cervical pleura; and (3) the thoracic duct on the left or occasionally an aberrant lymphatic duct on the right. Donald and Morton⁵ reported a case in which the thoracic duct was accidentally cut and ligated, with recovery. In cases with bilateral symptoms, only one side should be done at a time since Spurling¹¹ has shown that temporary paralysis of the diaphragm develops regardless of the care exercised in handling the phrenic nerve. The function of the diaphragm returns in about six weeks.

Intratracheal gas, oxygen and ether anesthesia is the best since positive pressure can be given in case the pleura is nicked. Cotton suture technic is used throughout. An anterior approach similar to that recommended by Adson¹ is used. An incision is made 2 cm. above and parallel to the inner half of the clavicle beginning at the sternal attachment of the sternocleidomastoid and extending laterally for a distance of 6 cm. The skin and platysma are incised and the clavicular portion of the sternomastoid is cut across. The external jugular is cut and ligated. The transverse cervical and suprascapular vessels and omohyoid muscle may be cut. The deep fascia should be cut across exposing the following structures from within outwards: (1) the carotid sheath; (2) the scalenus anticus muscle, running across which is the phrenic nerve; and (3) the third portion of the subclavian artery, behind which is the lower trunks of the brachial plexus. The carotid sheath is then retracted medially together with the phrenic nerve. The scalenus anticus muscle is dissected free from surrounding structures for a distance of several centimeters, care being exercised along its medial border to avoid injury to the thoracic duct. A curved hemostat is then placed underneath the muscle close to its insertion into the first rib. The muscle fibers are then cut across, a few at a time, with a sharp knife. Bleeding is controlled by figure-of-eight sutures of fine cotton, which are placed in the muscle before its posterior sheath is cut in order to avoid the difficulty of trying to stop the bleeding after the muscle retracts. One must be sure to cut all the fibers of the muscle and its posterior sheath. If any of the posterior sheath remains, the muscle cannot retract, and its ends may reunite. After the scalenus anticus is cut, the subclavian artery will usually fall

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forward over the distal end of the muscle. The proximal end of the cut muscle will retract for a distance of several centimeters. Ochsner believes a section of the muscle should be removed.

The procedure up to this point is considered adequate for cases in which symptoms are due to the scalenus anticus muscle alone. For those cases in which the pressure is between the cervical rib and the clavicle, or the brachial plexus appears to be under tension, a portion of the cervical rib must be removed. The subclavian artery is then separated from the brachial plexus



FIG. 4.—This is a case of right-sided cervical rib with costo-clavicular vascular compression. Note deviation of the head to the left to compensate for depression of the right shoulder, general atrophy of the right arm, and absence of the right third finger. (Case 1.)

trunks and freely mobilized. It is retracted downward in its second and third parts, and the lower trunks of the brachial plexus are gently retracted upward exposing the cervical rib. The rib is then separated from the cervical pleura and from the soft tissues beneath it. The rib is then cut across at about its middle and the anterior portion is removed. The posterior portion is ronguered away as high as possible without placing undue tension on the large nerves. If necessary, the lower nerve trunks may then be retracted downward and the stump of the rib exposed between the upper and lower trunks of the brachial plexus. Enough of the rib is ronguered away so as to allow plenty of room for the brachial plexus trunks without any tension or pressure. The neck of the

rib may be left behind since its removal is of no value and adds considerably to the difficulty of the procedure from this approach. The raw edges of the remaining segment should be rounded with a ronguer to avoid sharp margins. The sternomastoid muscle is then sutured as is the platysma. The skin is closed with silk. A firm pressure dressing is applied.

Postoperatively, there is a period in which edema and exudate will tend to put pressure on the subclavian artery. During this period the patient should avoid weight-bearing, throwing the shoulders back, carrying a pack, and prolonged use of the affected arm.



FIG. 5.—The tip of the thumb, postoperatively. The necrotic area has demarcated and the tissues beneath have almost completely healed. (Case 1.)

RESULTS

Of nine cases of cervical rib studied, four were symptomatic. In three of these the offending rib was on the right side and in one on the left. The one with symptoms on the left had a peculiar type of abnormality whereby the end of the rib hooked around the subclavian artery (Fig. 7). The symptoms were vascular in nature in three cases and were both vascular and neurologic in one.

The subclavian artery was shut off by the position of attention in six of the nine cases studied and in all the symptomatic cases. The pulse of the subclavian artery was occluded at the clavicle and not by the scalenus anticus muscle. Proof of this fact was obtained by palpating the pulse in the subclavian artery distal to the scalenus anticus muscle. When the patient went to the position of attention, a pulse beat could be felt in the third part of the subclavian artery at the base of the posterior triangle of the neck. At the same time, no pulse could be felt in the axillary, brachial, or radial arteries. Many persons can shut off the pulse by forcibly pressing the shoulders down and back. We consider this of no pathologic significance. The test is considered positive only if the pulse is shut off or markedly diminished by the position which the soldier considers attention. Velinsky¹⁴ studied 108 officer school candidates in order to determine how many normal individuals shut their pulse off at attention. He found three, and of these only one was normal. Of the remaining two, one had cervical rib and the other a history of circulatory disturbances indicative of costoclavicular compression.

Although occlusion of the subclavian artery appeared to be mechanical in nature there is some evidence it may be partly a result of spasm. Frequently the pulse shut off when the position of attention was assumed quickly, but not when it was done slowly. Further, after the pulse had been occluded for a few

seconds it was more readily shut off by a second test. These findings leave one with the impression that a neurogenic factor is added to the mechanical one. In the first instance, a quick stimulus brought about by pressure of the clavicle against the sympathetic nerve fibers produced spasm of the vascular tree. In the second place, the primary occlusion made the blood vessels more sensitive to spasm when the test was repeated.

The pulse was shut off by the Adson maneuver in only one case. In this case, traumatic fibrositis was found present in the scalenus anticus muscle at operation. However, in every case operated upon, the scalenus anticus was found to be producing some pressure on the subclavian artery, proving the necessity of dividing this muscle, as advised by Adson.

Symptoms are more common on the right side in right-handed individuals. In the cases studied, 60 per cent of the cervical ribs on the weight-bearing side were symptomatic while the ribs on the nonweight-bearing side gave symptoms in only 15 per cent of the cases. The right side was considered the weight-bearing side except in left-handed individuals.

The length of the rib and the position of the distal end appear to be important factors in production of symptoms. In all six cases in which the pulse was occluded at attention, the rib was 4 cm. in length or greater, and the shortest distance from the center of the spine to the tip of the rib 6 cm. or greater.

Of the four symptomatic cases one was relieved by medical measures consisting of avoidance of weight-bearing, carrying of packs, or throwing the shoulders back at attention. Exercises aimed at the strengthening of the levator scapulae and trapezius muscles were given.⁶ Surgery was necessary in three cases. A scalenotomy was performed and the greater part of the rib was removed. The scalenus anticus was found to be producing considerable pressure on the subclavian artery in all three cases. It was greatly hypertrophied in all cases and in one it had two heads of insertion on the first rib. In one of these cases in which a scalenotomy had previously been done, the muscle ends had grown back together again. Some of the fibers had become inserted into the artery. Recurrence can be avoided by dividing the muscle low down near its insertion so that it may retract. The results were uniformly good, with no complications.

One case had occlusion of the radial artery by thrombosis. The brachial pulse was present, but could be occluded by assuming attention. Gangrene had begun in three fingers. The radial pulse beat returned six weeks after operation. The necrotic areas on the thumb and little finger demarcated and healed. The sloughing stump of the middle finger rapidly healed. The hair grew back on the arm and the skin regained its normal texture. All the degenerated nails came off and new ones replaced them (Fig. 6). His arm rapidly regained its function. After operation, the brachial pulse would no longer shut off when he came to attention. Two men were returned to six months temporary limited duty, with the intention of placing them on full duty later. One man was placed on full general service two months postoperatively, at his own request.

REPORT OF CASES

Case 1.—A white male, age 30, was admitted to the Regional Hospital, Camp Joseph T. Robinson, Arkansas, August 11, 1944, with a painful draining sinus of the middle finger of the right hand of 11 months duration. His past history and family history were irrelevant. He gave a history of first having had trouble around Thanksgiving of 1942 during a spell of cold weather, while employed as a civilian locomotive fireman in Louisiana. Symptoms were soreness at the tip of the index finger, blueness of the nail, as if it had been "mashed with a hammer," and whiteness, numbness, and coldness of the hand, accompanied by a tingling sensation. This condition continued for the remainder of that winter and neither progressed nor improved until the onset of warm weather in April, when symptoms disappeared. The finger healed and he remained well until after



FIG. 6.—The hands of Case 1 two months after surgical removal of a right cervical rib. Note the marked improvement in blood supply as indicated by the quality of the skin and the color. The nails, atrophic from preoperative ischemia, are in the process of separation and are being replaced by new ones. (Case 1.)

his entrance on active duty December 15, 1943. In January, 1944, while he was taking his basic training in Louisiana, symptoms returned, but this time it was the middle finger of the right hand that was first involved. The tip of the finger became sore, and the nail became discolored as had the one on the index finger previously. The skin began to peel. The right hand ached a great deal and became blanched at times, particularly on cold days. An aching pain developed along the inner side of the right arm and shoulder with progressive weakness and atrophy of the arm. He began to rely more and more on the use of his left hand. Soon the condition became so severe that the right arm would become numb and white when he attempted to shave and the razor would fall from his hand. In spite of this, he completed basic training. Infection developed around the nail of the right middle finger and the nail was removed at a dispensary. Even though the wound did not heal, the true nature of his condition was not recognized at that time. He was transferred to Camp Joseph T. Robinson, Arkansas, April 20, 1944.

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Roentgenologic examination of the right hand revealed some rarefaction of the bones and a loose piece of bone in the distal phalanx of the middle finger. On March 5, 1944, the distal phalanx of the middle finger was amputated. The wound failed to heal and continued to discharge until August 20, 1944, when a reamputation was performed and this time soft-tissue flaps were designed. The wound healed in the hospital, but broke down very soon after return to duty. On September 14, 1944, a cervical rib was discovered and attention was directed to the true nature of his condition for the first time. At this time the radial pulse was absent. The brachial pulse was still present at the antecubital space. A scaleniotomy was performed. The immediate postoperative results were apparently good. The radial pulse was reported to have returned shortly after the operation. The lesion on the middle finger "healed miraculously." In spite of these apparent immediate beneficial results, the original symptoms rapidly returned when he resumed training. His right hand would become numb and cold while drilling, particularly on cold days. The wound on the middle finger broke down again. In addition to this, a similar process began on the thumb and little finger. He was readmitted to the hospital when on examination it was discovered for the first time that the structure of counter pressure obliterating the subclavian artery against the first rib was not the scalenus anticus muscle, but the clavicle. The proof of this finding was: (1) the cervical rib could be clearly felt in the posterior triangle of the neck just behind the clavicle with the subclavian artery intervening; and (2) when the position of attention was assumed the clavicle pressed firmly against the expanded end of the cervical rib and the brachial pulse disappeared. The subclavian pulse, however, could be clearly felt in the posterior triangle of the neck well lateral to the scalenus anticus muscle. When the shoulder was forward the pulse beat could be felt in the brachial artery in the antecubital space. The Adson maneuver did not obliterate the pulse. No pulsation could be detected in the radial artery at all. There was trophic disturbance of the right hand. The skin was thin and scaly, hair had ceased to grow, and the nails were thin and brittle. The arm was smaller in diameter than the left. There was an amputation stump on the middle finger on the end of which was a nonhealing wound; the proximal phalanx only remained. There was beginning gangrene at the margin of the nail on the little finger and at the tip of the thumb (Fig. 5).

On January 2, 1945, he was operated upon a second time. A scaleniotomy was performed and the greater part of the first rib was removed. It was found at operation that the subclavian artery was constricted considerably by the scalenus anticus muscle. The muscle ends had reunited since the previous operation. Some of the muscle fibers were actually inserted into the artery. The cervical rib was behind the third portion of the subclavian artery, its expanded tip articulated with the first rib. It was obvious that the subclavian artery could have been occluded between the expanded end of the cervical rib and the clavicle. Postoperatively, the brachial pulse no longer shut-off at attention, and in six weeks the radial pulse had returned. The condition of the hand and function of the arm rapidly improved. The necrotic area on the thumb separated by a definite line of demarcation (Fig. 5). The raw areas on the middle and little fingers also healed rapidly. The atrophic nails came off and new ones grew in their place (Fig. 6).

On March 1, 1945, he was operated upon for a revision of the amputation stump of the middle finger. A small area of osteomyelitis was found at the tip of the bone. *Staphylococcus aureus hemolyticus* was cultured. The wound was closed and healed *per primam*. At the time of this writing, eight months after operation, he is symptom-free, and has returned to duty.

COMMENT.—Symptoms of ischemia developed during the cold weather and improved in the summer, indicating that there was a spastic factor added to the mechanical factor. The mechanical factor was brought about by an obliteration of the subclavian artery between the expanded end of a high cervical

rib and the clavicle. The scalenus anticus muscle, although a factor, was not important in the production of symptoms in this case. A scaleniotomy was first performed, with temporary beneficial effect. Symptoms promptly recurred when he returned to drilling. The divided scalenus muscle had reunited by scar tissue. A second operation, consisting of scaleniotomy and removal of a portion of the cervical rib, resulted in a cure. Roentgenologic examination, December 6, 1944, showed a rarefaction of the bones. Following operation, the calcium was again deposited in the bones. This case demonstrates that a scaleniotomy should be performed low, near the first rib, so that the upper end of the muscle can retract. Otherwise, the muscle ends will grow together again. It also shows the importance of removal of a part of the first rib in addition to scaleniotomy.

Case 2.—A white male, age 22, with over four years service, was admitted to Regional Hospital, Camp Joseph T. Robinson, Arkansas, February 19, 1945, complaining of pain along the medial side of the right arm and hand, together with a tingling sensation in the ring and little fingers. Six years before admission, he had noticed that the right hand would periodically become numb or "dead." This sensation lasted only a few minutes and was relieved by moving the shoulder. He suffered an attack once while painting a shelf at a low level and the paint brush fell from his hand. Four years ago, shortly after induction, he noticed attacks of pain along the ulnar side of the forearm brought on by marching. Pain occurred with equal regularity while marching with or without a pack. He gradually became worse until even writing or typing would cause the right arm to "go to sleep."

In January, 1945, the condition suddenly became worse. Discomfort consisted of tingling along the median aspect of the right hand and forearm, and pain in the angle of the scapula. Neurologic examination showed hypo-esthesia along the distribution of the ulnar nerve, no reflex changes, fibrillary twitching, or atrophy. It was found that when he assumed the position of attention, his brachial pulse was obliterated. The Adson maneuver was negative. Roentgenologic examination showed a long, slender, right cervical rib, measuring 6.5 cm. from its tubercle to the tip. Physical examination was otherwise negative. On March 9, 1945, a scaleniotomy was performed and the greater part of the cervical rib was removed. The subclavian artery was constricted considerably by the scalenus anticus muscle. Some of the posterior muscle fibers and the posterior sheath were actually attached to the artery. The lower roots of the brachial plexus were stretched over the sharp upper margin of the cervical rib.

Postoperatively, the numbness and tingling along the course of the ulnar nerve gradually cleared up. Two months postoperatively, he was entirely symptom-free and his pulse was no longer obliterated by the position of attention.

COMMENT.—This patient had manifestations of both vascular and neurologic disturbances. Depression of the shoulder in painting produced attacks. Swinging the arms in marching produced irritative neurologic symptoms from friction of the lower trunk of the brachial plexus being rubbed over the sharp margin of a cervical rib. The pulse was not occluded by the scalenus anticus muscle, but it was completely obliterated by the clavicle when he assumed the position of attention. Some fibers of the scalenus anticus muscle were adherent to the subclavian artery. This indicates that all the fibers of the muscle must be carefully divided during a scaleniotomy.

CERVICAL RIB

Case 3.—A white male, age 18, entered on active duty January 23, 1945. One month later he noticed numbness in the left arm while carrying a pack on long hikes. Later in March, he noticed similar numbness in his left hand on waking in the morning. Roentgenologic examination revealed a cervical rib on the left side. On physical examination, it was found that the pulse to the left arm was shut off by the position of attention and by the Adson maneuver. He was operated upon May 28, 1945. The scalenus anticus muscle was divided and the greater part of the left cervical rib was excised. The thoracic duct was exposed during the procedure, but it was not injured.

The operative findings were as follows: The scalenus anticus muscle, which was greatly hypertrophied, had two heads of insertion into the first rib, and was adherent to the subclavian artery in its lateral part. The artery was compressed by the scalenus

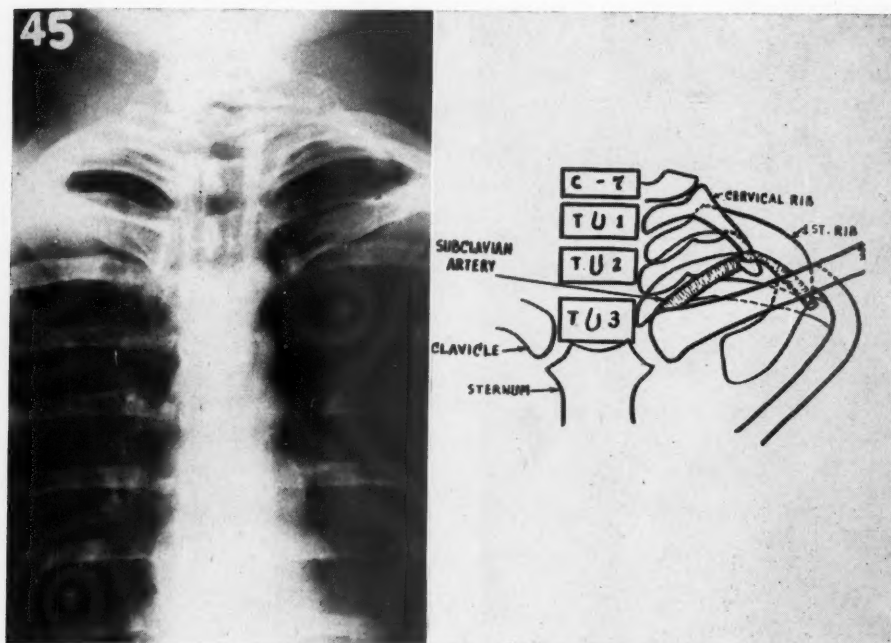


FIG. 7.—A left-sided cervical rib producing symptoms because of an unusual abnormality in which the subclavian artery was suspended from a bony hook. The deep groove in which the subclavian artery lies represents an attempt on the part of the neurovascular structure to cut through this rib during embryonic life. (Case 3.)

anticus muscle and it was elevated and pulled upward into the neck by adhesions to the scalenus muscle and to the aberrant rib. It was also adherent to the brachial plexus by numerous adhesions. The distal end of the cervical rib was situated just behind the lateral border of the scalenus anticus muscle, and was hooked around the third part of the subclavian artery. A fibrinous band extended from the tip of the cervical rib to the first rib.

Postoperatively, the patient had no complications. He returned to temporary limited duty at the end of the third week at his own request. One month later he requested and was given full military duty. The pulse no longer shut off at attention.

COMMENT.—It is uncommon to have symptoms on the left side. In this case, however, there was an unusual abnormality in that the first rib was hooked around the third part of the artery. The Adson maneuver was positive,

probably because of the fibrositis in the muscle, traumatic in nature, as a result of intermittent pressure from the clavicle.

Case 4.—A white male, age 18, entered on active duty October 16, 1944. In May he noticed a tingling sensation in the right arm while carrying a pack. The fingers became blanched and he rubbed and shook his hands to promote circulation. Shortly thereafter he noticed that, while leaning back in the theater watching a show, his arms would "go to sleep." He wondered why his feet did not go to sleep also. While on long hikes his right arm and hand would become numb requiring him to shift the rifle and readjust the shoulder straps of his pack to obtain relief. While both arms were affected

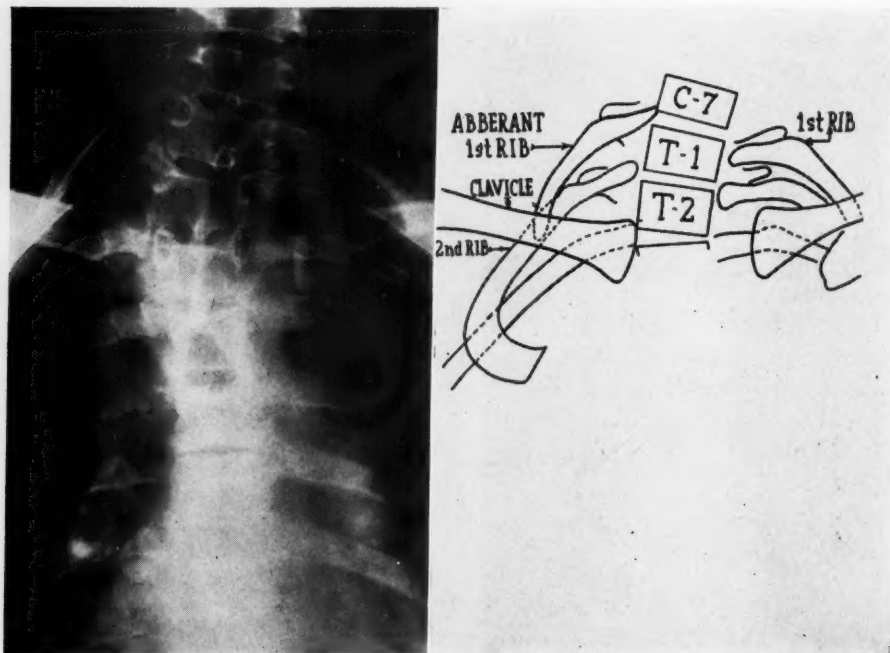


FIG. 8.—An abnormal first thoracic rib. The developmental abnormality of this case is clearly shown to be due to too rapid caudad progression of the neurovascular structures to the arm shearing off the distal part of the first thoracic anlage during embryonic life. As pressure was applied to the distal end of the rib, the proximal end was levered more cephalad. Compare the relative level of the heads of the first thoracic ribs on each side and note that the one on the right side is higher.

at times, the condition was more noticeable on the right side. Physical examination revealed a cervical rib in the right posterior triangle of the neck. When the shoulders were thrown back the pulse shut off on both sides, more readily on the right. Neurologic examination was negative; there was no trophic disturbance. Roentgenologic examination revealed a bilateral cervical rib; the right being the longer measured 4 cm. in length and the tip was 6 cm. lateral to the midline. He was given a period of limited duty and was told to avoid carrying a pack, weight-bearing, or throwing the shoulders back at attention. He was instructed in exercises to strengthen the levator scapulae muscles and elevate the shoulders.⁶ On July 23, 1945, when he was called in for reexamination, he was symptom-free.

DISCUSSION.—The vascular symptoms in these cases of cervical rib were the result of occlusion of the subclavian artery by the clavicle acting as the factor of counter pressure. The proof of this is that when the patient threw his shoulders back shutting off the pulse to the arm, the subclavian artery could be felt pulsating in the posterior triangle of the neck. If the scalenus anticus muscle was the factor of counter pressure, one would expect the pulse to be occluded in the second part of the subclavian artery as well. If the occlusion was due entirely to vasospasm resulting from sympathetic irritation, one would not expect the axillary artery to be occluded at the same time as the brachial since they have different sympathetic nerve supply. However, a spastic factor was superadded to the mechanical one, as previously mentioned.

The strenuous physical exertion of basic military training tends to produce symptoms by: (1) elevation of the thoracic cage from excessive use of the muscles of extraordinary respiration; and (2) carrying of a pack and prolonged standing at attention, which causes the shoulder to be pushed down and back resulting in vascular and nerve pressure.

Four patients were seen in whom vascular symptoms were present without any cervical rib. In all of these, the pulse was obliterated by position of attention, but not by the Adson maneuver. They were treated by being relieved from carrying a pack, by exercises designed to elevate the shoulder by strengthening the trapezius and levator scapulae muscles. They were instructed not to throw the shoulders back at attention. Costoclavicular syndrome is considered a suitable term to identify such a type of case. The cause of this condition is believed to be due to a narrowing of the space between the clavicle and the first thoracic rib.

In the cases with cervical ribs, here reported, the costoclavicular factor appeared to predominate in those with long laterally placed ribs and the subclavian artery was occluded in the third part. In the case of a more medially placed rib, the scalenus anticus was found to be an important element of counter pressure and the second part of the subclavian artery was usually involved.

The "Adson maneuver" is a test designed to determine the rôle played by the scalenus anticus. Pressure is supposed to be exerted on the subclavian artery by turning the head toward the side of the lesion, hyperextending the neck and taking a deep breath. Turning of the head in this manner would not be expected to put tension on a normal scalenus muscle since the muscle should reciprocally relax in the same manner in which the quadriceps relax when the hamstrings contract. The muscle should become longer and thinner without any change in tension. However, if this muscle was the seat of fibrositis or stretched beyond physiologic capacity, as in older age-groups, tension would develop. Ochsner⁹ proved the presence of fibrositis in his cases. In our series, a younger age-group, the Adson maneuver was positive only in one rib case.

Surgery is aimed at increasing the size of the costoclavicular space by removing the scalenus anticus muscle and the cervical rib.

SUMMARY

Up until the present time, it has been generally believed that symptoms from cervical rib are produced in many cases by pressure from the scalenus anticus muscle. This we have found to be partly correct. However, in the cases presented here of young men in military service, it was found that the important structure of counter pressure is the clavicle. Vascular symptoms are produced by the subclavian artery being occluded between the cervical rib and the clavicle. In these cases the pulse was occluded partially or completely by the clavicle when the position of attention was assumed. When surgery is indicated in such cases, a partial excision of the cervical rib should be performed in addition to scaleniotomy.

In addition to crowding from a cervical rib and a hypertrophied scalenus anticus muscle, the costoclavicular space may be further narrowed by: (1) elevation of the thoracic cage; and (2) depression of the shoulder. The first conditions are brought about by excessive use of the muscles of extraordinary respiration such as the sternocleidomastoids and the scalene group; and the second, by carrying a pack, and prolonged periods of standing in the position of attention.

The longer the rib, the greater the possibility of costoclavicular compression. Ribs 4 cm. or more are liable to be symptomatic. The more laterally placed the tip of the rib is the more liable it is to produce symptoms. Ribs which extend 6 cm. or more lateral to the center of the spine were found to be symptomatic. Right-sided cervical ribs produce symptoms four times more often than those on the left.

Nine cases of cervical rib are here reported, in six of which the radial pulse was occluded in the position of attention. All but one of these had vascular symptoms. One case had thrombosis of the radial artery and beginning gangrene of three fingers of the right hand. Three cases were operated upon, at which time a scaleniotomy and partial removal of the cervical rib was performed. There was no mortality and no sequelae. Results were all good.

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RESECTION OF THE LEFT LOBE OF THE LIVER FOR MESENCHYMOMA

REPORT OF CASE

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RESECTION of the entire left lobe of the liver has been reported on four previous occasions. Keen¹ removed the left lobe, in 1899, for carcinoma, using the cautery, catgut ligatures and iodoform packing. Peck² resected the left lobe for an angioma weighing about 1.8 Kg. He used the clamp and ligature method for the control of hemorrhage. Pickrell and Clay³ reported the successful removal of the left lobe in three cases. They emphasized the fact that total extirpation of the left lobe of the liver is more easily and safely accomplished than excision of only the part bearing the lesion. The reasons for this are: the thinness; relative avascularity; and greater capacity for holding sutures which the insertion of the round ligament confers on the line of junction of the two lobes. Lobectomy offers the additional advantage of wider excision of the pathologic tissue. Their method of resection consisted of cutting between two rows of mattress sutures placed in the interlobar sulcus. The conditions for which they performed left lobectomy were: carcinoma, hemangioma and gumma. (The last was diagnosed as carcinoma or a giant tuberculoma at the time of operation.) Van Prohaska⁵ has recently reported excision of the left lobe for a solitary metastatic carcinomatous nodule. Resection was accomplished by cutting alongside hemostatic mattress sutures. Clamps and ligatures were used for some of the larger vessels as they were encountered. There have been many reports on partial hepatectomy^{1, 4, 6} but this paper deals only with resection of the entire left lobe of the liver.

The performance of left lobectomy of the liver is rare enough to warrant this single case report of successful resection for an unusual lesion.

Case Report.—J. T., a six-year-old white boy, was admitted to the Babies Hospital, November 20, 1944, because of an epigastric mass. One week previously he complained of cough and vomiting and was treated for acute coryza. The abdominal mass was discovered during the physical examination for that illness. The parents had no previous knowledge of the mass nor of any symptoms referable to the abdomen. The mass was not observed during physical examination before tonsillectomy one year prior to this admission. The personal and family histories were noncontributory.

Examination revealed a tall, thin boy who did not appear acutely ill. His temperature, pulse and respirations were normal. Blood pressure 96/74. The physical findings were within normal limits except for examination of the abdomen. There was a firm, nontender mass in the epigastrium somewhat to the left of the midline—measuring about six centimeters in diameter. It was well forward in the abdominal cavity and not separable from the liver, the edge of which was palpated one centimeter below the costal margin in the right nipple line and which moved with the mass during inspiration, though with a smaller

RESECTION OF LEFT LOBE OF LIVER

excursion. Percussion over the mass was dull; over the left hypochondrium tympanitic. No other mass or organ was palpable in the abdomen. The hemoglobin was 14.5 Gm. and the red blood cells 5,040,000. The leukocyte count was 6,800, with 45 polymorphonuclear cells, 51 lymphocytes, 3 monocytes and 1 eosinophil. The urine analysis, platelet count, bleeding and coagulation times were all within normal limits. The nonprotein nitrogen was 36.9, and the blood sugar 59 mg. per cent. The sedimentation rate was 2 mm. in the first half-hour and 6 mm. in one hour. The tuberculin test was negative to .01 mg. The Kline test was reported negative.

Roentgenologic examination of the gastro-intestinal tract showed that the stomach was compressed and displaced laterally by a large mass which projected into its medial aspect. The stomach emptied readily, all of the barium being evacuated at the end of one hour.



FIG. 1.—Cut-surface of the inferior half of the tumor. The left margin represents the free border of the left lobe.

On December 7, 1944, under ether anesthesia, a celiotomy was performed through an upper left rectus incision. A large cystic mass, measuring 7.5 cm. in diameter, was found taking up most of the left lobe of the liver and projecting from its under surface. A thin shell of liver tissue remained over the mass anteriorly (Fig. 1). The right lobe appeared to be perfectly normal. Aspiration in several places yielded approximately 60 cc. of dark brown fluid resembling old blood. The liver was mobilized by cutting the falciform ligament near its diaphragmatic attachment and by incising the left triangular ligament. The dissection began in the interlobar fissure on the inferior surface of the liver, exposing the left hepatic bile duct and the left branches of the hepatic artery and portal vein. These were individually ligated with braided silk. The left lobe was then resected by cutting through the liver substance at the fissure. The hepatic veins from the left lobe were ligated during this dissection. Remarkably little bleeding occurred during the entire procedure. A few interrupted silk sutures were used through the falciform ligament and the inferior surface of the liver to cover part of the cut area. The remaining cut-surface of liver tissue was then covered with a layer of oxidized cellulose gauze and this was left *in situ*. The abdomen was closed in layers, without drainage. The patient received 300 cc. of whole blood and 100 cc. of normal saline during the procedure. He was given another 250 cc. of whole blood later in the day.

He made an uneventful recovery, and was discharged on his 14th postoperative day. On February 8, 1945, he had no complaints, and his wound was well healed. On May 14, 1945, he was symptom-free, and presented normal findings on examination. He was last seen on January 7, 1946 (about thirteen months postoperatively). He looked well, was developing normally, gaining weight and had no complaints.

FIG. 2

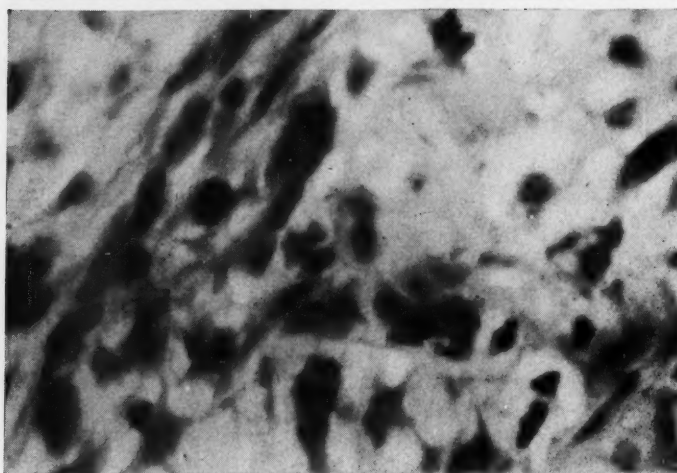
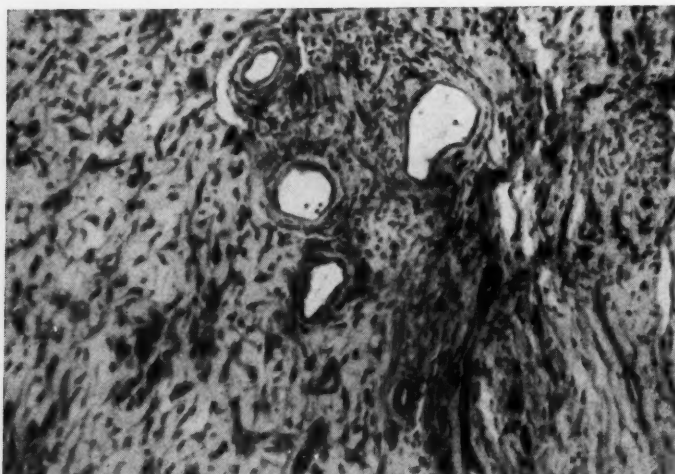


FIG. 3

FIG. 2.—Section taken near the periphery of the tumor showing angiomatous and mesenchymal tissue. (x1750)

FIG. 3.—High magnification of mesenchymal area showing multinucleated cells and embryonal fat cells. (x6250)

A summary of Dr. Dorothy H. Andersen's pathologic report follows: "The specimen consists of the left lobe of the liver which contains a large round tumor mass bulging from the inferior surface. The entire specimen weighs 318 Gm. The tumor measures 7.5 cm. in diameter. The liver measures 13 cm. in the transverse plane and 6.5 cm. in thickness. The surface of the mass varies in color and consistency. On section, the mass

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appears to be composed of tumor, portions of which have degenerated. The tumor is divided by sheaths of fibrous tissue into smaller areas, some of which are necrotic (Fig. 1). The largest such area occupies about one-quarter of the mass. Most of these areas are occupied by grayish-buff, translucent tissue which is soft. Others have a smooth lining and contain bloody serous fluid. The liver parenchyma itself appears to be normal. Microscopic sections show that the liver has been partly destroyed and replaced by an expansile and, to some degree, an infiltrating tumor of the most bizarre and complex appearance (Fig. 2). It varies so much in different areas that it is extremely difficult to describe. In general, it seems to be made up of a mesenchyme-like tissue which varies from ordinary embryonal mesenchyme by the fact that, not infrequently, its cells assume a bizarre multinucleated aspect. In some areas the mesenchyme seems to differentiate by the formation of capillaries. In others, there are nodules suggesting the appearance of lipoblastic tumor tissue; very occasionally, small areas of spindle-shaped tumor cells appear (Fig. 3). No satisfactory name has been devised for this type of tumor, especially in this solitary form which is distinctly neoplastic. Although expansile, it does not appear invasive and is everywhere enclosed by the thick fibrous capsule. Since it is apparently essentially a tumor of the mesenchyme, it will be called a mesenchymoma of the liver."

SUMMARY

(1) Successful left lobectomy for an unusual primary tumor of the liver is presented.

(2) Mobility of the liver is achieved by cutting the falciform ligament at its diaphragmatic attachment and by incising the left triangular ligament.

(3) A method is presented for controlling hemorrhage, the major problem in liver resections. This is accomplished by ligating the left branches of the hepatic artery and portal vein in the interlobar fissure. The hepatic veins are ligated as encountered.

(4) Oxidized cellulose gauze may be used effectively to check the bloody ooze from the cut-surface of the liver (after all major bleeding has been controlled).

We desire to express our appreciation to Dr. Allen O. Whipple for his advice and assistance.

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POSTOPERATIVE ATELECTASIS AND PNEUMONIA

DIAGNOSIS, ETIOLOGY AND MANAGEMENT BASED UPON
1,240 CASES OF UPPER ABDOMINAL SURGERY

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DURING THE PERIOD July, 1941 to October, 1945 there were 1240 upper abdominal operations completed at the Hospital of the University of Pennsylvania. On the basis of data obtained from this group of patients it is our opinion that the incidence of postoperative atelectasis and pneumonia can be sharply reduced if a rational prophylactic regimen is observed prior to surgery, during operation, and immediately following operation. Indifferent attention to such a program will inevitably be followed by a rise in postoperative respiratory morbidity, particularly in individuals to whom general anesthesia has been administered.

There have been scores of papers on the subject of postoperative pulmonary complications. Certain broad principles relating to etiology and treatment have been established, and, on the basis of these, what formerly constituted one of the chief hazards of surgical convalescence has now become much less of a danger, despite the fact that surgeons today are performing more extensive operations, and are likewise subjecting older and older patients to surgical intervention. The background for this decrease in respiratory morbidity is a comprehensive one. Among the contributing factors should be included the development of anesthesiology as a medical specialty, greater knowledge of the preoperative preparation of the surgical patient, the application of physiologic principles to therapy, the introduction of chemotherapy and antibiotics, blood banks, and blood substitutes. The combination of these and other advances enables the surgical patient to anticipate a postoperative course marked by minimal disturbance of function. This paper will not present any fundamentally new concepts, therefore, but will concern itself with details, the minutiae which are essential to the successful application of well-recognized general principles.

As stated above, this study was begun in July, 1941. An analysis of the first 250 cases was completed in December, 1942 (Series I). Certain facts became apparent at once. The incidence of postoperative atelectasis and pneumonia was 11.0 per cent for patients receiving inhalation anesthesia, and only 4.2 per cent in the group given spinal anesthesia. Since it has been conclusively proven by many investigators^{1, 2} that the anesthetic agent and technic are not major factors in postoperative morbidity, it was evident that something was amiss. Accordingly, a positive program was adopted for the management of patients scheduled for inhalation anesthesia. An analysis of the next 990 upper abdominal operations (Series II—December, 1942 to October, 1945)

demonstrated the efficacy of the change. Following spinal anesthesia the incidence of atelectasis and pneumonia in the postoperative period had remained essentially unchanged (5.0 per cent), whereas after inhalation anesthesia the incidence had decreased to 4.1 per cent. Since these data have proved statistically significant, it seemed of interest to report them and to attempt an explanation for our experience.

METHOD OF STUDY

There are two general surgical services at this hospital. One prefers general anesthesia, the other spinal anesthesia. These services use the same wards, operating rooms, anesthetists, interns and nursing staff. They care for the same general type of patient, since admissions are alternated from the receiving ward or are sent in by a large but relatively constant group of referring physicians. There has been, therefore, opportunity for more or less standardizing such factors as preoperative preparation of the patient, the ability of the anesthetist, surgical technic and skill, and postoperative care, leaving as the outstanding variable the method of anesthesia. This latter, of course, is not the sole variable, but the 1,240 cases are as carefully controlled as is possible in the average clinical case study.

The value of a statistical study of clinical material varies directly with the accuracy of each individual observation. In this particular instance accuracy in diagnosis determines statistical reliability. Failure to recognize even a few cases or inclusion of doubtful ones will alter final figures considerably unless the series be much larger than those usually reported. For this reason data gathered from hospital record rooms is more liable to error than is data obtained directly from each patient as that patient is being treated. The authors of this paper have, therefore, followed each case during the entire postoperative course until discharge from the hospital. Careful progress notes have been made in each instance.

It is unfortunate that diagnostic criteria for postoperative atelectasis and pneumonia have not been standardized, and many surveys have not indicated clearly the basis on which diagnoses have been established. There is general agreement as to the clinical picture and radiologic findings of the so-called "massive collapse," described first by Pasteur. Lobar atelectasis is also readily recognized. There are, however, a great many patients whose pulmonary status is equivocal. Diagnosis for these individuals ranges from "bronchitis" through "patchy or lobular atelectasis" to "pneumonitis or pneumonia." It is this larger group for which diagnostic standards will be discussed, for they form the borderline cases which are so difficult to evaluate.

We have made a diagnosis of patchy or lobular atelectasis in the presence of the following findings:

Symptoms.—1. *Cough:* Dry at start, soon becoming productive tenacious mucus, or mucopurulent secretions.

2. *Respiratory Distress:* A sense of discomfort over the lung field, vague tightness in the chest, or dyspnea.

Signs.—1. *Inspection:* Asymmetrical respiratory movements (retraction of affected side on inspiration, restriction of movement on affected side); slight cyanosis (not essential).

2. *Auscultation:* Diminished or absent breath sounds, râles (these may be coarse or fine).

3. *Percussion:* Dullness (not essential).

4. *Vital Signs:* Rise in pulse rate, respiratory rate, or temperature (the usual range in patchy atelectasis is 99–101 degrees F.).

Roentgenologic Findings.—1. *Linear Shadows:* Well-described by Fleischner, Hampton and Castleman,³ indicative of collapse of alveoli.

2. *Hypoventilation:* Increased density of lung tissue (decreased air-bearing), prominent trunk shadows.

3. *Elevation of Diaphragm, and Reduced Excursion of Diaphragm:* Seen in majority of upper abdominal cases whether or not signs and symptoms indicate pulmonary dysfunction.⁴

4. *Mediastinal Shift:* An uncommon finding unless the collapse involves many areas unilaterally.

If the clinical course is prolonged, if the febrile reaction decreases only slowly, if toxemia is evident, and if there are roentgenographic signs of consolidation, a diagnosis of bronchopneumonia is made.

The differential diagnosis between bronchitis and lobular atelectasis presents the greatest problem. If the only objective finding is a productive cough, with little febrile response, and little evidence of respiratory distress, the former diagnosis seems more accurate. Admittedly, there are instances in which we have erred, but our tendency has been to include doubtful cases in the category of major pulmonary complications.

All the data have been subjected to statistical analysis according to the method of chi-square.

RESULTS

I. *Incidence.*—The results of the entire group of cases are shown in Table

TABLE I
TOTAL INCIDENCE OF ATELECTASIS AND PNEUMONIA FOLLOWING
1,240 UPPER ABDOMINAL OPERATIONS

	No. of Cases	No. of Complications	Per Cent
Series I.....	250	19	7.6
Series II.....	990	49	4.9
	1,240	68	5.5

I, where it is seen that the incidence of postoperative atelectasis and pneumonia cases was 5.5 per cent in 1,240 cases of upper abdominal surgery. This incidence of 5.5 per cent must be compared to that expected in a general surgical service with all types of operations. Representative figures are those of Eliason and McLaughlin⁵ of 1.38 per cent in 22,962 cases, and of Taylor, *et al.*⁶ of 1.2 per cent in 12,349 cases. Thus, as has long been known, the incidence of major

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pulmonary complications in the postoperative period is distinctly greater after surgery in the upper abdomen.

II. *Anesthetic Method.*—Table II indicates the incidence of postoperative atelectasis and pneumonia in relation to the use of general anesthesia, spinal anesthesia, or a combination of these two methods. Analyzed statistically, there is no significant difference between the three groups of cases. Of statistical

TABLE II
INCIDENCE OF POSTOPERATIVE ATELECTASIS AND PNEUMONIA ACCORDING TO ANESTHETIC METHOD

	General			Spinal			Spinal Plus General		
	Cases	Compl.	%	Cases	Compl.	%	Cases	Compl.	%
Series I.....	90	10	11.1	144	6	4.2	16	3	18.7
Series II.....	343	14	4.1	543	27	5.0	104	8	—7.8
	433	24	5.5	687	33	4.8	120	11	9.0

significance, however, is the breakdown of cases in the group "general anesthesia." Series I shows a significant difference in incidence from that found for the entire group, and from that found in Series II.

These observations confirm a fact, also well-established, that the anesthetic method need not influence the incidence of respiratory complications in the postoperative period. Ferguson and Latowsky⁷ have published data, however, which indicate that general anesthesia is followed by major pulmonary complications four times more frequently than is spinal anesthesia. In Series I of our own figures the incidence in favor of spinal anesthesia is almost 3:1. How can one reconcile these two viewpoints? Why do many surgeons and internists insist, on the basis of personal experience, that spinal anesthesia is preferable if atelectasis or pneumonia are to be avoided?

The explanation for these differences in opinion lies in the fact that general anesthesia is more hazardous unless administered skillfully, and unless the patients receive conscientious, competent supervision in the immediate six hours postoperatively. Ferguson and Latowsky's figures were gathered in an institution where nurse-anesthetists or interns administered all of the general anesthesia, and where the importance of immediate postoperative care was not stressed repeatedly by the anesthesia and surgical staffs. Series I in this study represents somewhat similar conditions, particularly as regards postoperative management. This was entirely left up to the initiative of the nursing staff. In some instances care was excellent. In others the rationale underlying intelligent treatment of the unconscious patient was not appreciated at all. Postoperative rounds were not started until the whole schedule of cases was completed, so that physician supervision was often delayed for hours unless emergency measures were required. With such a regimen the incidence of postoperative atelectasis and pneumonia was significantly lower in those patients given spinal anesthesia. It is our opinion, therefore, that with mediocre anesthetic skill and indifferent or uninformed postoperative attendants spinal anesthesia is the safer method. If certain well-recognized measures are adopted, however, this need not be the case.

As stated in the introduction, we instituted a definite program for the management of surgical patients scheduled for general anesthesia when Series I revealed that our incidence of pulmonary complication was so much higher following this type of anesthesia. Table II indicates the value of this prophylactic program, the details of which will be presented:

PROPHYLACTIC REGIMEN

A. *Preoperative*.—(1) All cases with acute upper respiratory infections were postponed for one to two weeks unless the problem was a surgical emergency.^{8, 9}

(2) Patients with recent irritation of the respiratory passages were given larger doses of atropine, since such individuals tend to pour out a greater amount of secretion in response to inhalation anesthesia.

(3) Negroes were given larger doses of atropine (0.6-0.8 mg.) since they, too, seem to have greater tendency towards secretions. The value of the belladonna derivatives in preventing postoperative respiratory complications has been debated on many occasions. Opponents claim that increased viscosity of secretions results with tendency toward formation of plugs. DeTakats¹⁰ has recently denied this, nor have we seen any harmful effects. Large doses of atropine have been shown to prevent reflex bronchoconstriction and bronchorecretion following intra-abdominal manipulations, such as traction on the cystic duct or on the mesentery.¹⁰ Atelectasis has been reported occurring during surgery,¹¹ and it is possible that the reflex narrowing of bronchi together with increased secretions are predisposing factors in such instances. Atropine in larger than usual doses might therefore be justified as a prophylactic measure.

(4) Patients with chronic respiratory disease or irritation (bronchitis, bronchiectasis, heavy smokers, *etc.*) were urged to cough up the night's accumulation of secretions,¹² were placed later in the schedule so that this could be accomplished, and were even subjected to preoperative bronchoscopic aspiration if such measures as cough and postural drainage were insufficient in clearing the tracheobronchial tree. Wherever possible these patients were placed on the operating table in positions favorable for gravity drainage.⁹

The various mechanisms responsible for the elimination of secretions and fluids from the respiratory tract have been listed by Boyd, *et al.*¹³ These include the ciliary mechanism, cough, the milking-like contractions of the bronchial muscles, the churning movements of breathing and reabsorption into the lymphatics and veins of the lung. These workers found the cilia capable of moving an amount of respiratory fluid considerably in excess of that normally present. In the presence of congestion or edema of the tracheobronchial mucosa, however, drainage was inadequate and secretions pooled in the lungs. So long as the experimental animals remained horizontal, relatively little respiratory fluid was eliminated. Tilting to 30°-50° head-down increased the drainage 30-fold:

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Tracheobronchial Mucosa:	Intact	Congested & Edematous
Animals at angle 0°	3.2 cc./kilo/24 hrs.	1.7 cc./kilo/24 hrs.
Animals at angle 30°	3.5 cc./kilo/24 hrs.	32.7 cc./kilo/24 hrs.
Animals at angle 50°	3.6 cc./kilo/24 hrs.	34.1 cc./kilo/24 hrs.

This quantitative data clearly illustrates that respiratory disease is associated with accumulation of fluids, and that postural drainage is a valuable therapeutic measure in such instances.

(5) Oral hygiene was practiced, *i.e.*, correction of oral sepsis, use of mouth washes and brushing of teeth.¹⁴

B. During Surgery.—(1) The lightest plane of surgical anesthesia which was compatible with the task at hand was maintained. For example, during resection of the stomach, or during the anastomosis of the jejunum to the stomach in a gastric resection relatively light anesthesia sufficed. This was then increased during exploration, inversion of the duodenal stump, and closure. This substantially reduced the time required for postoperative awakening and the amount of anesthetic agent required. Many of the patients were awake before leaving the operating room.

(2) Anesthesia was stopped as a rule as soon as the peritoneum was closed. This permitted the patient to "blow-off" anesthetic agent, and also to fill his lungs with room air as respiration was stimulated by placing of the abdominal wall sutures. The presence of nitrogen in the alveoli is regarded as a prophylactic measure for collapse due to vascular absorption of readily absorbable mixtures high in oxygen content.¹³

(3) If patients with intestinal obstruction or gastric retention were operated upon under general anesthesia great care was taken to recognize any regurgitation of intestinal contents into the oropharynx. Although practically all of these patients had some form of suction-drainage prior to operation this was no guarantee against such an occurrence. When regurgitation was noted, immediate suction of the tracheobronchial tree was carried out through an endotracheal tube. Even in instances in which rather large amounts had been aspirated such a procedure was quite successful. These patients were bronchoscoped immediately after operation and the cleanliness of the respiratory passages was impressive. Tracheal suction can be instituted at once before a bronchoscopist can be summoned, and is apparently quite effective. Regurgitation and aspiration can occur with any type of surgery, of course, but these complications can be anticipated more frequently in the presence of intestinal obstruction. We also employ cuffed endotracheal tubes in cases of intestinal obstruction to prevent aspiration, but occasionally fluid has slipped past even this barrier.

C. Postoperative.—(1) The patient was turned at least every hour. A radical change in position was insisted upon from the nursing staff.

(2) Secretions in the nose and mouth were aspirated by catheter as often as necessary.

(3) Inhalation of 100 per cent CO₂ was prescribed for 2-3 minutes

(unless no hyperpnea developed) every 20-30 minutes for six hours, then every hour for 24 hours. The CO_2 was delivered from a tank at the bedside through a rubber tube held six inches from the patient's face. This permitted the inhalation of a mixture of CO_2 in air rather than in oxygen, minimizing absorption of alveolar gases during the post- CO_2 depression of breathing. The rationale of this has been discussed by Waters.

The value of CO_2 inhalations is a controversial matter. King¹⁰ treated 648 patients postoperatively with such inhalations, using another group of 667 individuals as controls. He was unable to demonstrate any decreased incidence of major pulmonary complications following CO_2 . It should be pointed out, however, that the treated cases were divided into several groups: One breathed an increased CO_2 mixture for three minutes three times a day; another for 3-6 times a day, while another received such therapy 6-10 times a day. We feel that the chief value of such inhalations lies in the first six hours, and insist that our patients receive this treatment 2-3 times an hour during that period. King's cases, in our opinion, did not receive CO_2 therapy of sufficient intensity to prove or disprove its value.

A recent report by Mushin and Faux¹⁷ is interesting along this same line. These workers demonstrated a decreased incidence of postoperative respiratory morbidity in a series of 24 patients placed in a respirator for the first 24 hours postoperatively. Since such a procedure ensured full respiratory movements, one can use such data to substantiate the belief that the respiratory stimulation caused by frequent exposure to CO_2 mixtures is valuable.

We propose to employ a similar approach by hyperventilating patients with a positive pressure technic soon to be described. Again, the virtue of full respiratory excursions (together with the increased speed of elimination of anesthetic agent) can be submitted to analysis.

(4) Narcotics were kept to a minimum and codeine sulfate was used whenever possible for the relief of pain. There were two reasons for this practice. First, we desired to maintain the cough reflex as active as possible. Second, morphine suppresses ciliary activity considerably, interfering with elimination of secretions from the respiratory tract.¹⁸

(5) The abdominal wall was supported whenever the patient could be made to cough. This was accomplished manually, and not with binders. Adhesive was limited to the maintenance of light gauze dressings.

(6) Aged individuals were mobilized as early as possible.¹⁹

(7) Intestinal suction tubes were removed early to avoid nasal and pharyngeal irritation with outpouring of secretions.

(8) Chemotherapeutic or antibiotic agents were administered prophylactically if respiratory morbidity was especially likely.

(9) We have only rarely attempted to improve ventilation by blocking painful impulses from the operative site. Starr and Gilman²⁰ describe an increase in vital capacity (23 per cent) following unilateral intercostal block in eight patients who had had biliary tract operations. This is worthy of further study, particularly if a safe, long-lasting local anesthetic can be discovered.

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Johnson²¹ appears to have minimized postoperative complications following pneumonectomy by crushing the intercostal nerves supplying the operative site.

(10) Finally, the problem of postoperative complications was placed squarely before the nursing staff as a challenge. They were instructed in the rationale of the "stir-up regimen";²² they were praised for the successful management of difficult cases and shared in our concern when a complication arose.

With the institution of the program outlined above, the incidence of postoperative atelectasis and pneumonia following general anesthesia decreased from 11.0 per cent to 4.1 per cent, an incidence slightly lower than that seen after spinal anesthesia.

That these two methods of anesthesia should have a similar incidence of postoperative respiratory morbidity is not strange when one considers that regardless of the anesthetic technic the surgical patient's resistance is lowered to the same degree in each instance by his primary disease, the insult of surgery, exposure to drafty corridors and to the respiratory flora of attendants. It has been argued that the decreased ventilation associated with high spinal anesthesia (block of intercostal muscles) predisposes to atelectasis; and that as the patient awakens from an inhalation anesthetic, he tends to struggle, retch, move about and, hence, expand pulmonary alveoli more efficiently than the individual recovering from spinal. For these reasons some anesthetists expect a higher respiratory morbidity following this latter technic. Most reports, however, indicate no statistically significant difference.

The importance of the immediate postoperative care of surgical patients is being increasingly recognized. Lundy²³ describes a "postanesthetic room" staffed by personnel specially trained in the management of the unconscious patient, and fully equipped to handle all emergencies. These observation rooms should form an integral part of all surgical services, for they can almost certainly reduce postoperative morbidity and mortality.

III. *Anesthetic Agent.*—Table III presents the incidence of atelectasis and pneumonia following various general anesthetics. Analyzed statistically,

TABLE III
INCIDENCE OF ATELECTASIS AND PNEUMONIA FOLLOWING GENERAL ANESTHESIA LISTED
ACCORDING TO ANESTHETIC AGENT

	Series I		Series II		Total		
	Cases	Compl.	Cases	Compl.	Cases	Compl.	%
Ether.....	84	8	232	10	316	18	5.7
Cyclopropane.....	6	2	23	3	39	5	12.8
Cyclo. and curare or dihydro-B-erythroidin.....	0	0	87	1	87	1	1.1
Local and pent.....	0	0	1	0	1	0	

there is no significant difference between the various drugs. The extremely low incidence of respiratory complications following the combination of cyclopropane and curare or dihydro-B-erythroidin deserves comment. A larger series of cases is required before definite conclusions can be reached, but it is highly suggestive that the use of an inhalation anesthetic to produce uncon-

sciousness and of another substance to produce muscular relaxation is a valuable technic as far as postoperative respiratory morbidity is concerned. The data also indicate that ethyl ether does not constitute the threat to the lungs which is assumed by many internists. The relatively high morbidity after cyclopropane alone is probably due to the fact that this agent was selected for individuals whose physical status was abnormal. These patients respond with an increased incidence of postoperative complications by the very nature of their debility.

IV. *Endotracheal Tubes*.—Table IV indicates the influence of an endotracheal tube on the development of atelectasis or pneumonia. Although the percentage of complications is greater in the presence of endotracheal technics,

TABLE IV
INCIDENCE OF ATELECTASIS AND PNEUMONIA FOLLOWING GENERAL ANESTHESIA LISTED
ACCORDING TO USE OF ENDOTRACHEAL TUBE

	Series I			Series II			Total		
	Cases	Compl.	%	Cases	Compl.	%	Cases	Compl.	%
With tube.	69	9	13.0	234	10	4.3	303	19	6.3
Without tube. . . .	21	1	4.7	109	4	3.7	130	5	3.9

these data are not statistically significant. This agrees with the findings of other workers.^{24, 33} In the presence of preëxisting upper respiratory tract infection endotracheal intubation may be followed by increased respiratory morbidity, but the value of this form of anesthesia is so great that when indicated it should not be withheld because of the hazard of a postoperative pulmonary complication.

V. *Age of Patient*.—In Table V are listed the number of cases according to age-groups, together with the percentage of respiratory complications and the statistical significance of the data.

TABLE V
THE INCIDENCE OF POSTOPERATIVE ATELECTASIS AND PNEUMONIA ACCORDING TO THE AGE OF PATIENT

Years	No. of Cases	Atel. and Pneum.	%	Significance
1-20.	22	2	9.0	0
21-30.	129	6	4.7	0
31-40.	213	5	2.4	+
41-50.	296	18	6.1	0
51-60.	355	19	5.3	0
61-70.	180	11	6.1	0
71-80.	32	6	18.7	+
81-90.	4	1	25.0	0
?	7	0	0	0

This relationship is perhaps better illustrated by a graph (Chart I).

It would appear that there was a period of maximal resistance in the age-group 31-40, with susceptibility increasing considerably in patients over 70 years of age. This has been noted by Taylor, *et al.*⁶

VI. *Sex of Patient*.—Table VI indicates the sex distribution in this series of cases. As has been pointed out before^{2, 25} the incidence of pulmonary com-

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plications is significantly higher in men than in women. Of all of the many reasons given for this sex difference the one which appeals to the authors is the suggestion of Ravdin and Kern²⁵ that women have a higher resistance to infections of the respiratory tract. A survey of comparable populations in an effort to demonstrate this point would be profitable. Other theories listed

TABLE VI

THE INCIDENCE OF POSTOPERATIVE ATELECTASIS AND PNEUMONIA ACCORDING TO SEX

	No. of Cases	Atel. and Pneum.	%
Male.....	501	45	90
Female.....	739	23	31

include the greater incidence of smoking in men,³⁴ and the fact that respirations are more diaphragmatic in men and, hence, more affected by intra-abdominal surgery. Women seem more able to withstand pain. Could the difference in respiratory morbidity be due to the fact that men are more apt to splint respiratory muscles because of discomfort?

VII. *Duration of Operation.*—Table VII lists the incidence of atelectasis and pneumonia according to the duration of the surgical procedure. Again none of the data are statistically significant. It is interesting, however, that

TABLE VII

THE INCIDENCE OF POSTOPERATIVE ATELECTASIS AND PNEUMONIA ACCORDING TO THE DURATION OF OPERATION

Hours	No. of Cases	Atel. and Pneum.	%	Significance
0-.5.....	14	0	0	0
.5-1.....	346	14	4.0	0
1-1.5.....	329	15	4.6	0
1.5-2.....	212	14	6.6	0
2-3.....	227	11	4.9	0
3-4.....	85	9	10.5	0
4-5.....	20	4	20.0	0
5.....	7	1	14.3	0

respiratory morbidity does not begin to increase until after the third hour of surgery. Since many of the radical procedures for management of biliary tract obstruction, or intra-abdominal malignancy require a prolonged operative time this fact is reassuring. It should be recognized, however, that other surveys⁶ indicate a linear relationship between the incidence of postoperative respiratory complications and duration of operation.

VIII. *Type of Operation.*—Table VIII indicates the relationship between the type of operation and the postoperative respiratory morbidity. Several facts are apparent from these data. First, gastric surgery, as a whole, is followed by the highest incidence of atelectasis and pneumonia. For example, Mimpriss and Etheridge²⁶ report 30 instances of atelectasis in a series of 100 consecutive partial gastrectomies. Second, emergency surgery or surgery upon ill patients is more of a hazard. This accounts in all probability for the increased incidence following cholecystostomy, cholecystenterostomy, gastro-enterostomy and

TABLE VIII
RELATION OF POSTOPERATIVE ATELECTASIS AND PNEUMONIA TO TYPE OF OPERATION

Operation	General Anesthesia				Spinal Anesthesia				Spinal and General				Total								
	Series I		Series II		Series I		Series II		Series I		Series II		Series I and II								
	Cases	Compl.* %	Cases	Compl.* %	Cases	Compl.* %	Cases	Compl.* %	Cases	Compl.* %	Cases	Compl.* %	Cases	Compl.* %							
Biliary Surgery:																					
Cholecystectomy.....	47	4	9	114	0	0	84	3	4	195	4	2	11	2	18	27	1	4	478	14	3
Cholecystectomy and																					
choledochostomy.....	2	0	0	22	1	5	20	0	0	70	2	3	2	0	0	8	1	13	124	4	3
Cholecystostomy.....	0	0	0	12	4	33	4	0	0	40	5	13	0	0	0	4	0	0	60	9	15
Choledochostomy.....	1	0	0	6	0	0	3	0	0	13	1	8	2	1	50	1	0	0	26	2	8
Cholecystenterostomy.....	2	0	0	5	0	0	4	1	25	5	1	20	1	0	0	3	0	0	20	2	10
Plastic on common duct.....	0	0	0	7	0	0	5	0	0	8	0	0	0	0	0	3	0	0	23	0	0
Biopsy of gallbladder.....	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	2	0	0	6	0	0
Repair of fistula.....	0	0	0	0	0	0	1	0	0	3	0	0	0	0	0	0	0	0	4	0	0
Gastric Surgery:																					
Resections.....	22	4	18	85	6	7	15	2	13	48	4	8				17	2	12	187	18	10
Gastro-enterostomy.....	5	2	40	10	1	10	4	0	0	9	1	11				2	0	0	30	4	14
Gastrostomy.....	2	0	0	9	0	0	3	1	33	12	1	9				0	0	0	26	2	8
Repair of ruptured ulcer.....	1	0	0	6	1	17	1	0	0	17	3	18				4	0	0	29	4	14
Polypectomy.....	0	0	0	2	0	0	0	0	0	1	0	0				0	0	0	3	0	0
Pyloroplasty.....	0	0	0	1	0	0	0	0	0	1	0	0				0	0	0	2	0	0
Upper Abdominal:																					
Exploratory celiotomy.....	4	0	0	24	0	0				28	1	4				8	0	0	64	1	2
Exploratory celiotomy and biopsy																					
or elysis of adhesions.....	3	0	0	5	0	0				15	0	0				2	0	0	25	0	0
Splenectomy.....	0	0	0	11	1	0				7	1	14				7	1	14	25	3	12
Ileotransverse colostomy.....	1	0	0	2	0	0				13	1	8				5	1	20	21	2	10
Other bowel surgery.....										12	0	0				3	1	33	19	1	5
Pancreatic adenectomy or re-																					
section.....				7	0	0				5	1	20				0	0	0	12	1	8
Transperitoneal nephrectomy.....				1	0	0				2	0	0				0	0	0	3	0	0
Adrenalectomy.....				2	0	0				0	0	0				0	0	0	2	0	0
I & D subdiaphragmatic abscess...				3	0	0				6	0	0				0	0	0	9	0	0
Marsupialization of liver cysts....				0	0	0				1	0	0				1	0	0	2	0	0
Sple-rectomy and nephrectomy....				1	0	0				0	0	0				0	0	0	1	0	0
Colectomy.....				4	0	0				28	1	4				7	0	0	39	1	3

* Compl. = Number of patients with atelectasis or pneumonia.

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repair of ruptured ulcer. In the present series the incidence of atelectasis and pneumonia after cholecystectomy is low (3 per cent), as is that following partial gastric resection (10 per cent).

IX. *Economic Status of the Patient.*—It has been suggested² that the poorer classes of people are more likely to suffer from chronic respiratory tract diseases, particularly chronic bronchitis, and that it is this group which should

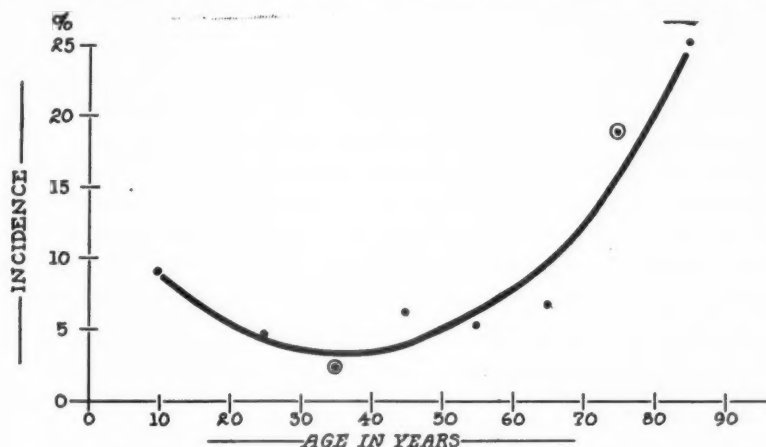


CHART I.—Relation of age of patient to incidence of postoperative atelectasis and pneumonia. (The circled points are statistically significant.)

show the highest incidence of postoperative atelectasis and pneumonia. Table IX is a study of the 1,240 cases divided according to their status as ward, semiprivate or private patients. We do not believe that this breakdown is a reflection of the original physical status of the patient. More likely explanations for the difference in incidence include the fact that most of the semiprivate and private patients had individual nurses caring for them, and had the benefit of surgeons of greater experience.

TABLE IX
THE INCIDENCE OF ATELECTASIS AND PNEUMONIA ACCORDING
TO THE ECONOMIC STATUS OF THE PATIENT

	Cases	Compl.	%
Private.....	192	6	3.1
Semiprivate.....	395	13	3.5
Ward.....	653	50	7.7

TREATMENT

Once the diagnosis of atelectasis was established certain definite therapeutic efforts were made. These varied with the degree of collapse. In the presence of massive or lobar collapse either tracheobronchial toilet, as described by Waters,²⁷ or bronchoscopic aspiration³² was immediately instituted. The

advantage of the former method is that it can be carried out by the anesthetist who is readily available; it is an atraumatic procedure and an effective one. The activation of the cough reflex by stimulation at the carina removes secretions from the bronchioles even though the suction catheter does not reach the obstructing material directly. On the other hand bronchoscopy as performed at this hospital is also a relatively simple, bedside maneuver which we do not hesitate to employ. It is unfortunate that many clinicians feel such a valuable therapeutic tool to be too hazardous for the ill patient. This has not been our experience.

If patchy or lobular atelectasis was found, more conservative measures were attempted first. These included slapping the patient on the back vigorously with the flat of the hand, encouragement to cough with the operative incision well supported, and the introduction into the trachea of an urethral catheter passed nasally, according to the method of Haight.²⁸ A theoretic objection to this latter technic of tracheobronchial aspiration is that alveolar gases may be sucked out as the vocal cords close around the aspirating catheter. Thus, further collapse might result. This objection can be overcome by passing the aspirating catheter through a wide-bored endotracheal tube.

Finally, each patient with atelectasis was placed upon sulfadiazine or penicillin therapy to prevent development of bronchopneumonia.

In several recent articles other conservative approaches have been suggested. We have had no experience with these. They include administration of ascorbic acid in an attempt to decrease pulmonary capillary permeability,²⁹ the use of large doses of ammonium chloride as an expectorant to liquefy tenacious bronchial secretions together with ephedrine as a bronchial dilater,³⁰ and the use of postural drainage.³¹

DISCUSSION.—The data presented in this paper serve merely to confirm other surveys of the relation of the anesthetic agent and method, the age, sex and economic status of the patient, and the duration and type of operation to the development of atelectasis and pneumonia in the postoperative period. We feel that our figures are of value for two reasons. First, they have been subjected to statistical analysis; and, second, they offer statistical evidence that general anesthesia is more likely to be followed by respiratory morbidity unless a rational prophylactic regimen is carried prior to surgery, during surgery and after surgery. There is, therefore, justification for the feeling of many clinicians that regional or spinal anesthesia is preferable from the standpoint of pulmonary complications. In hospitals in which unskilled anesthetic technic and unintelligent postoperative care characterize the management of the surgical patient such an opinion is sound. It must be emphatically pointed out, however, that such a sequence of events represents poor medical and surgical management. Our data, and those of other workers, conclusively demonstrate that the patient under general anesthesia need not anticipate a higher incidence of respiratory morbidity. Since many surgeons and many patients prefer this method of pain relief this point must be emphasized.

This survey lends impetus to the movement publicized by Lundy and directed towards the addition of an observation room to hospital facilities. Such a room will contribute materially towards a reduction in postoperative morbidity. Surgery has now reached a point where it can offer the patient an extremely low mortality rate. We are no longer as concerned with whether a patient will "come off the table." This is expected in the vast majority of operations. Rather, our concern is directed toward minimizing disturbance of function in such a way that the patient's operative and postoperative course is as smooth as possible. One's ultimate goal is that of minimal morbidity. For the respiratory tract this can be achieved only by attention to the details listed above. With surgeons preparing their patients more adequately for operation, with anesthetic skill available through the services of a specialist in this branch of medicine and with competent postoperative nursing in an observation room such a goal can be realized.

We also wish to urge more standardization in the diagnosis of atelectasis. In some English and Canadian reports it is difficult to avoid the conclusion that rather marked degrees of collapse are required before the condition is listed. Their classification of "chest" includes many instances of productive cough, fever and dyspnea which we feel are associated with patchy or lobular atelectasis. Criteria should be established so that data from various clinics can be more uniformly compared.

Should pulmonary embolus be included in a study such as this? There can be no doubt but that such a catastrophe must be classed as a respiratory complication. There is considerable doubt in our minds, however, as to whether intelligent management of the respiratory tract during surgery or postoperatively can affect the incidence of this complication. The occurrence of thrombophlebitis is related to the broad problem of anesthetic management, *e.g.*, poor position of the patient with resulting venous obstruction, low blood pressure with resulting thrombus formation, *etc.*; but these conditions do not involve the respiratory tract primarily and should be considered separately. The data of deTakats¹⁰ which suggests that emboli may be the forerunner of certain cases of atelectasis in no way affects this reasoning. It is only by defining a condition clearly that one can subsequently define the problems requiring solution. Atelectasis and pneumonia fall into one group, embolus into another. To combine them invites confused thinking.

What are the problems of atelectasis? In this and other papers the clinical picture of atelectasis has been described. We find that the incidence is higher: (1) in men; (2) in smokers; (3) after surgery in the upper abdomen; (4) in patients with acute or chronic respiratory infections; (5) with increasing age; and (6) with increasing length of operation.

Faced with these clinical facts, various investigators have studied the respiratory tract, attempting to correlate alteration of function with bedside observations. Thus, a number of experimental facts have been equally well established. It can be stated with certainty that after abdominal surgery one can expect: (1) A sharp reduction in vital capacity;^{35, 36, 37} (2) a decrease in sub-

tidal volume of the lungs;³⁸ (3) an elevation of the diaphragm;⁴ and (4) a decreased excursion of the diaphragm.⁴

These mechanical changes produce hypoventilation of the lungs. The question is, does hypoventilation alone cause the clinical picture of atelectasis or must there be an additional factor, such as bronchial obstruction? If one could eliminate hypoventilation in the postoperative period by blocking painful impulses from the incision, by ensuring full respiratory movements with CO₂, a respirator or by positive pressure breathing, could atelectasis be prevented? We propose to test this hypothesis by forcing patients to ventilate under conditions of increased pressure within the respiratory tract.

If bronchial obstruction is found to be a requisite, there is another problem to be solved. Is atelectasis caused by absorption of alveolar gases behind an obstructing plug, or is the collapse secondary to the creation of negative pressure behind mucus moving up the bronchioles through ciliary action? This latter thesis has been advanced by Hilding³⁹ after a series of ingenious experiments.

Finally, there is the problem of reflex atelectasis. How important are the reflex bronchoconstrictor and bronchosecretory phenomena described by deTakats? What are the nerve pathways over which these reflexes are mediated and what can be done towards their prevention?

Once the relative importance of hypoventilation, secretions and afferent impulses is established one can hope for a further reduction in the incidence of postoperative atelectasis. With careful attention to theoretic and practical details, it is our opinion that this reduction in incidence can approach zero.

SUMMARY

(1) The incidence of postoperative atelectasis and pneumonia in 1,240 cases of upper abdominal surgery is reported. The data are analyzed statistically from the standpoint of anesthetic agent and method, the age, sex and economic status of the patient, and the type and duration of operation.

(2) Factors concerned with the prevention of these respiratory complications are listed and a prophylactic regimen is outlined.

(3) Current theories as to the etiology of atelectasis are discussed and problems requiring further investigation are defined.

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A TWO-STAGE MASTOPEXY IN PLASTIC SURGERY OF MARKEDLY ENLARGED BREASTS*

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OF NECESSITY, excessively enlarged breasts often require surgical help. Because of their marked size, a one-stage mastopexy is usually impractical to obtain the desired result. We have previously described the one-stage operation for reconstruction of enlarged pendulous breasts. However, when their size is of great proportions a two-stage procedure is desirable.

The purpose of the surgery is four-fold: (1) To obtain small breasts with reasonable size, shape, symmetry and contour. (2) To reconstruct two nearly identical breasts. (3) To obtain intact nipples and their areolae in the desired position. (4) To avoid loss of tissue following the surgery.

When breasts are of exaggerated size, the two-stage operation will meet all of these requirements and reduce variations to a minimum. Because such large breasts are usually functionless, the prime purpose of the operation is to obtain a small breast of the desired proportions. Suitable reconstruction of such enlargements cannot be accomplished with a one-stage mastopexy without danger of losing either portions or all of the nipple and skin flaps.

A two-stage operation, with transplantation of the nipple, may be utilized in such cases. We have described such a procedure but in our opinion the final result is not as satisfactory as the two-stage procedure, with transposition of the nipple.

SURGICAL PROCEDURE

Under general anesthesia, the patient is placed on the operating table in a semisitting position with the arms akimbo. The operative area is prepared and suitably draped. The lines of incision are measured and marked with 3 per cent gentian violet solution (U. S. P.) The primary incision is a circle around the nipple areola usually measuring 48 mm. in diameter. From the center of the upper edge of this circle an incision is carried perpendicularly upward to within 12 mm. of the new nipple site. From the lower center of the circle an incision is carried perpendicularly downward to the inframammary line some four inches long forming an inverted "T" with the previous incision.

The skin over the whole breast is thoroughly undermined, forming two reasonably thick flaps. All bleeders are clamped and sutured with white No. 3-0 silk. The breast is entirely denuded of skin leaving the nipple and required amount of areola attached.

* Presented in conjunction with colored surgical motion pictures to the Riverside County Medical Society, Riverside, California, March 12, 1945 and the Los Angeles County Medical Society (Bay District Section) June 19, 1945.

FIG. 1-A

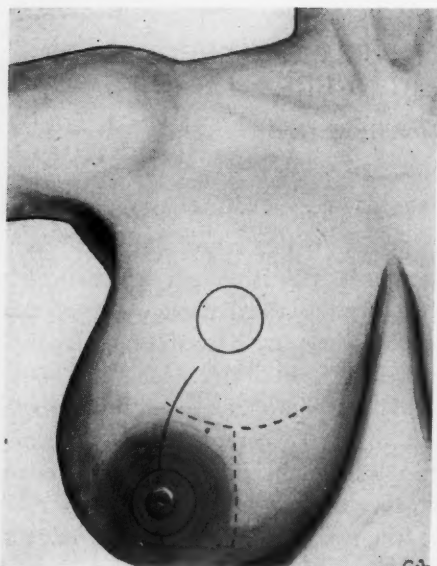


FIG. 1-B

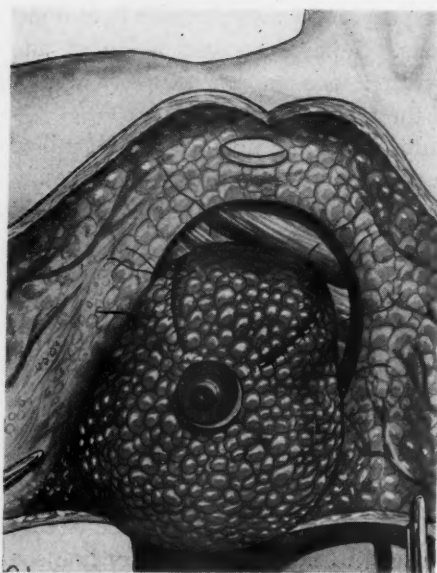
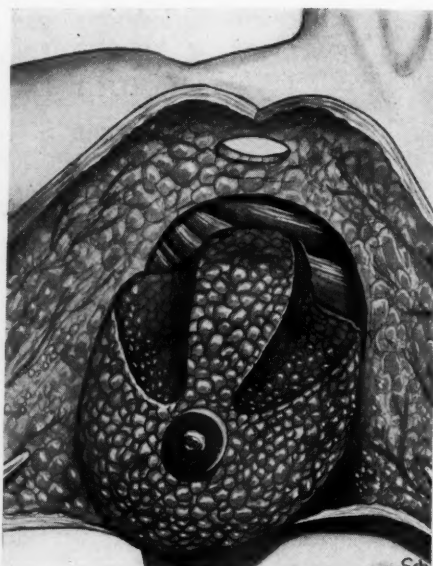


FIG. 1-C

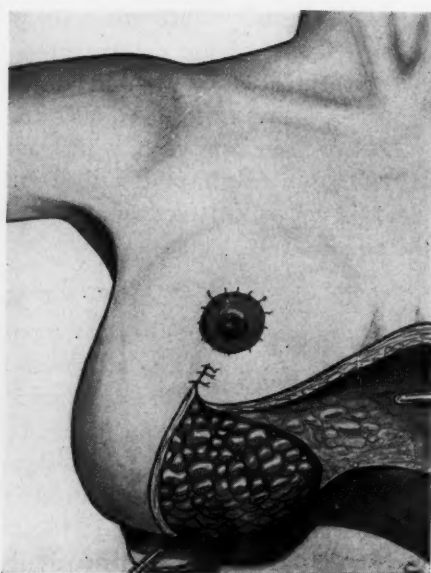


FIG. 1-D

FIG. 1-A.—The incisions are measured and marked with 3 per cent gentian violet (U. S. P.) The lines of incision to form the flaps as well as the new residence for the nipple and the attached areola are meticulously marked.

FIG. 1-B.—The skin flaps have been dissected away, leaving the denuded breast with the required amount of areola and the nipple attached. The circular button of skin has been resected to receive the areola in its new position.

FIG. 1-C.—The walls have been sutured with silk. Four silk sutures (No. 4) are taken through the pectoral fascia over the second rib and passed through the upper pole of the breast to fix the latter in the desired position.

FIG. 1-D.—The areola has been carefully sutured to its new residence. The flaps are trimmed and temporarily sutured.

TWO-STAGE MASTOPEXY

FIG. 1-E

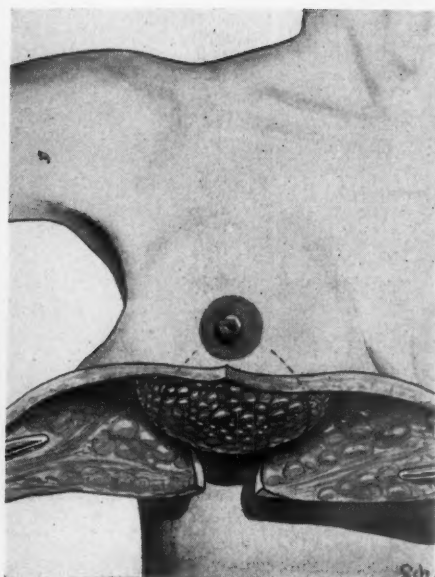
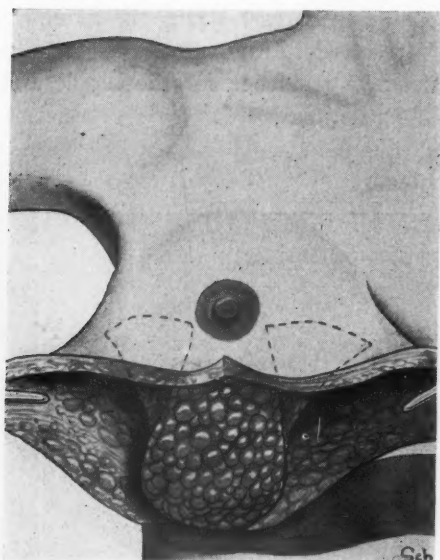


FIG. 1-F

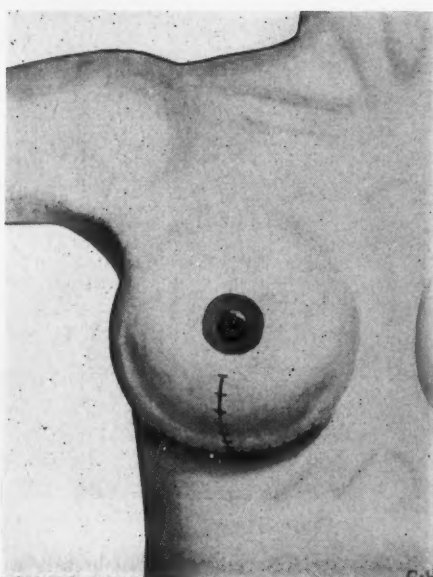


FIG. 1-G

FIG. 1-E.—Ten days to two weeks later the flaps are dissected free and two triangular wedges are resected from the lower pole of the breast.

FIG. 1-F.—The walls are sutured with silk and the flaps are trimmed and fitted to the contour of the newly constructed breast.

FIG. 1-G.—The operation has been completed. The flaps are sutured with interrupted silk sutures, resulting in an inverted "T."

Two triangular wedges of tissue are resected from the upper pole of the breast proper. The walls are approximated with No. 1 white silk. Four No. 4 silk sutures are taken through the pectoral fascia over the second rib, then through the upper pole of the breast, fixing the latter in the desired position.

A circle of skin is resected 12 mm. above the upper perpendicular incision and this serves as the new residence for the nipple and its attached areola. The latter is sewn into position.

FIG. 2-A

FIG. 2-B

FIG. 2-C

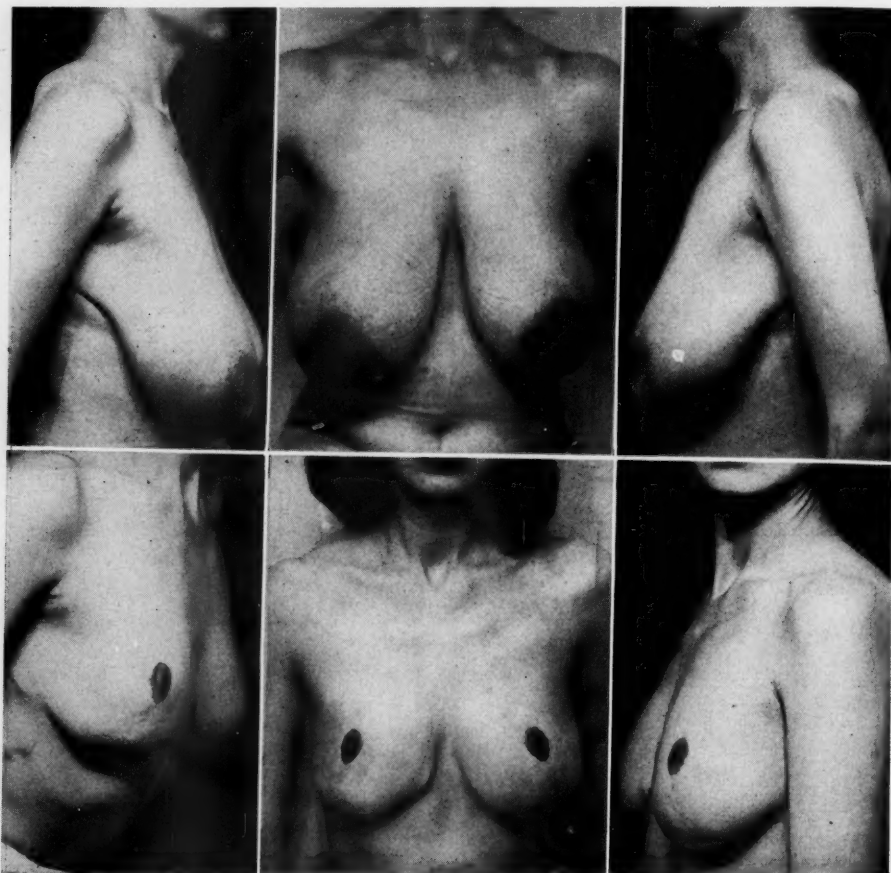


FIG. 2-D

FIG. 2-E

FIG. 2-F

FIG. 2-A.—Uniformly enlarged breasts with marked pendulousness.

FIG. 2-B.—Depicting the asymmetry between the two breasts and enlargement of the areolae.

FIG. 2-C.—The weight of the breasts has caused the patient to be round-shouldered with heavy shoulder strap marks in conjunction with poor general posture.

FIG. 2-D.—The two-stage mastopexy resulting in uniformly smaller breasts and areolae.

FIG. 2-E.—The breasts have been reconstructed to fit the patient and at the same time the excess weight and pendulousness have been eradicated.

FIG. 2-F.—The newly constructed breasts allow the patient to regain a more normal posture and eliminate her previous marked discomfort.

TWO-STAGE MASTOPEXY

FIG. 3-A. — Enlarged breasts causing general debilitation, poor posture and deep shoulder strap marks.

FIG. 3-B. — Breasts with such marked enlargement require a two-stage operation to obtain smaller breasts of the desired size, shape and symmetry.

FIG. 3-C. — Depicting the marked enlargement, with the right breast larger than the left.

FIG. 3-D. — Six weeks following the two-stage mastopexy showing the inverted "T" scar. The latter fades quite appreciably with the passage of time.

FIG. 3-E. — The breasts have been re-constructed to a uniformly smaller size, shape and contour.

FIG. 3-F. — The weighty pendulousness and marked discomfort have been eradicated.

FIG. 3-C

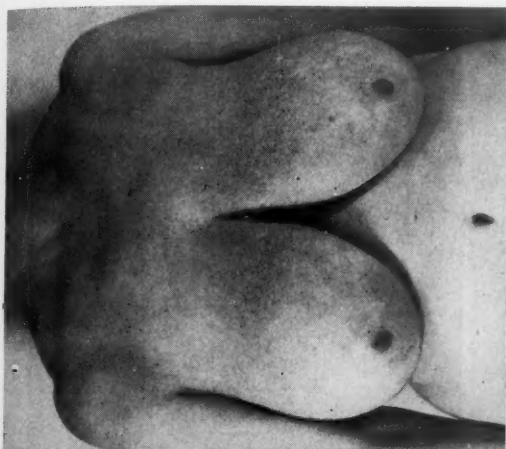


FIG. 3-B



FIG. 3-A

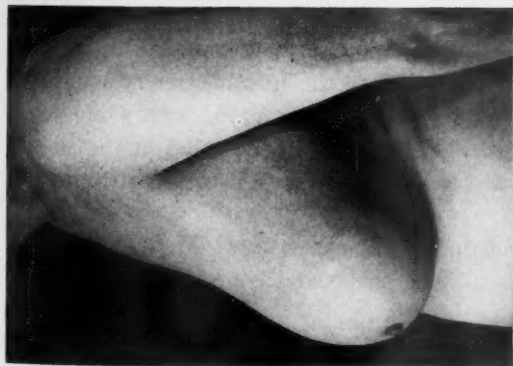


FIG. 3-F



FIG. 3-E



FIG. 3-D



The excess skin from both flaps is trimmed and the latter are temporarily sutured. A large Penrose drain is inserted upward through each corner of the inframammary incision.

A similar procedure is repeated on the opposite breast. Moderate pressure dressings are applied and the patient is returned to bed and placed in a semi-Fowler position.



FIG. 4-A



FIG. 4-B

FIG. 4-A.—Large pendulous breasts.

FIG. 4-B.—Reconstruction of the breasts in a two-stage mastopexy.

Second Stage: Ten days to two weeks later, the perpendicular incision below the nipple, as well as the inframammary wound are opened. The flaps on either side are easily separated, exposing the denuded lower poles of the breast. Two triangular wedges are resected from either side of the lower pole. The walls are approximated with white silk. Sulfanilamide crystals may be sprinkled into the wound. The two flaps on either side are trimmed to fit the contour of the reconstructed breast. If necessary the inframammary incision is lengthened slightly on each side. The skin is approximated with white silk (No. 4-0) subcutaneously and black silk (No. 4-0) interrupted in the skin. Two Penrose drains are placed upward through each corner of the inframammary incision.

A similar procedure is carried out on the opposite breast. Meticulous care is taken that both breasts are of equal size, shape and contour and that the lines of incision match in position and length.

TWO-STAGE MASTOPEXY

A moderate pressure dressing is applied and the patient is returned to bed and placed in a semi-Fowler position.

SUMMARY

The method described allows for plastic reconstruction of excessively enlarged breasts with a minimum danger of losing any tissue. At the same time the procedure presents sufficient elasticity so that the surgeon may create small breasts of the desired proportions from an exaggerated deformity.

Gentleness in handling tissue, meticulous surgery, careful planning of the procedure and a knowledge of the surgical anatomy are presupposed.

A MINUTE GRANULOSA CELL TUMOR, WITH VAGINAL BLEEDING

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IN SPITE of the intensive interest directed toward granulosa cell tumors in recent years this type of tumor is still a source of considerable speculation and controversy. Granulosa cell tumors are not considered uncommon any longer. They are found in 4 per cent of all ovarian neoplasms, and 21.4 per cent of all ovarian carcinomas. They occur at any age—48.7 per cent during the child-bearing period, 42.5 per cent after the menopause, and only 8 per cent in the prepuberal period. The majority of the cases present a clear-cut picture,—a tumor that is usually unilateral, and whose average size is that of an orange. Atypical menses, enlarged breasts and enlargement of the uterus usually occur, and 70 to 85 per cent show abnormal bleeding. Fifteen to 25 per cent of them are malignant; recurrence occurs in about 10 per cent, usually late (15 years in some cases). Symptoms and signs regress after removal of the neoplasm. The case presented, herewith, is unusual because it is such a small granulosa cell tumor to be associated with abnormal vaginal bleeding. Although 70 to 85 per cent of all granulosa cell tumors show biologic activity (abnormal bleeding and hyperplasia), tumors that are so small as to be mere collections of epithelial cells rarely are associated with biologic activity. As a rule, such collections are discovered in routine pathologic examinations, and have been designated "*granulosa-ballen*," and, although they do not show any hormonal behavior, they are credited with being precursors of granulosa cell tumors. It is unusual to have such a long period of biologic activity as shown by the case herein presented, the patient having had irregular bleeding for nine years; such prolonged bleeding is a rarity even in fully developed tumors; the history of the average granulosa cell tumor gives indications of activity for only a matter of months to a few years. That the minute neoplasm in the case herein reported gave no evidence of growth during all these years is also uncommon, because records show that the size of the average granulosa cell tumor is somewhat in proportion to the amount and duration of its activity.

Case Report.—The patient had had three admissions to the hospital. On her first admission she was 14 years old. Her complaint was vaginal bleeding, spotting continuously for three months. Her periods had been normal since the menarche, six months prior to the onset of this episode of bleeding. Pelvic examination under anesthesia was entirely negative. A diagnosis of dysfunctional bleeding, puberal in type, was made.

On her second admission she was 21 years old. She came to the hospital because of profuse vaginal bleeding for one month. She gave a history of intermittent irregularity of her periods since puberty, but she never previously had such a persistent, profuse episode of bleeding, without pain. Diagnosis of possible abortion was made. A curettage was done, but no pregnancy was found. Again, a diagnosis of hormonal bleeding was made.

On her third, and last, admission, again for vaginal bleeding, she was 23 years old.

GRANULOSA CELL TUMOR

She stated that she had bled continuously since her previous admission, about two years ago. Pelvic examination at this time showed a small mass in the left adnexal region. At operation, this was found to be a thickened tube wrapped around a normal-sized ovary. The tube and ovary were inseparable and, therefore, both removed, partial resection of the remaining tube was done. Microscopic examination of the ovary revealed the granulosa cell tumor.

Microscopic Examination.—Dr. Robert Meyer: "The small, rounded aggregation of epithelial elements represents the folliculoid type of granulosa cell tumor, with a very rare dissipation to some small nodules and single strands of cells of the same type in other parts of the ovary. They are lying partially in the hilum of the ovary and partially in the medullary part, with a few small nodules reaching into the cortex. The structure of this folliculoid tissue is the same as in the ordinary granulosa cell tumor. The cells are largely swollen and clear, due to lipoid deposition. In the portion lying in the hilum are some irregularly-shaped heaps and cords of epitheloid interstitial cells as well as single interstitial cells. In the same field some of the folliculoid parts are in such a degree of regression that only large disk-like droplets, the contents of former vacuoles, remain." (See illustrations).

DISCUSSION.—Pelvic inflammatory disease as a cause of bleeding in our case is not tenable because she has had irregular vaginal bleeding since her menarche nine years ago—and evidence of pelvic inflammatory disease was absent even a number of months before operation.

The facts in this case—irregular bleeding since the menarche (nine years previously). cured by removal of an apparently normal ovary that harbored a small granulosa cell tumor 3 mm. in diameter, seem to indicate clearly enough the etiology of the disturbance. However, a careful evaluation was necessary in order to arrive at a proper conclusion, due to the vagaries of the dysontogenetic group of tumors and the paucity of cases reported under 1 cm., associated with biologic activity.

That numerous cases of dysontogenetic neoplasms should have been reported that do not follow the expected pattern of behavior is understandable because of the differences in interpretation. For instance, E. H. Norris,¹⁰ believes a diagnosis is not justified by microscopy alone, and that pre- and postoperative endocrine studies are necessary (this is a very impractical procedure in most cases). Schiller,¹² on the other hand, believes that microscopic study should be the all-important criteria in their diagnosis, because clinical pictures can be confusing since ovaries can produce virilizing effects and testes can produce folliculin. Geist and Gaines³ reported two cases with masculinizing syndromes in which they found scattered throughout the cortex and medulla numerous groups of large foamy cells distributed diffusely throughout the ovary in irregular strands and accumulations of varying sizes, but in neither case did removal result in regression of symptoms, so that these biologic changes could only have been secondary to changes in the pituitary or adrenals; similar changes could also be due to gonadotropins, as in hydatidiform mole or chorioepithelioma.

Robert L. Blackmun¹ reported a case of masculinization in which the ovary showed pathology similar to the cases reported by Geist and Gaines,³ and operation in this case cured the patient. The pathologic picture in all these

FIG. 1

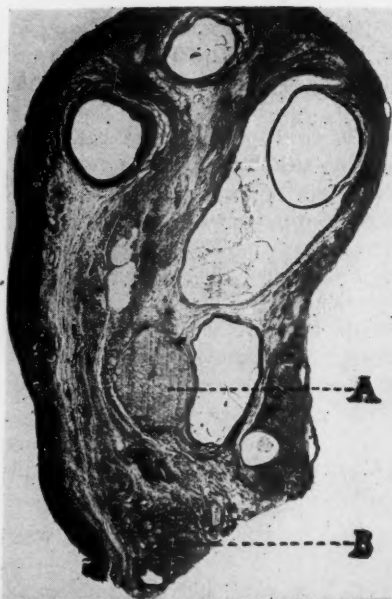


FIG. 2

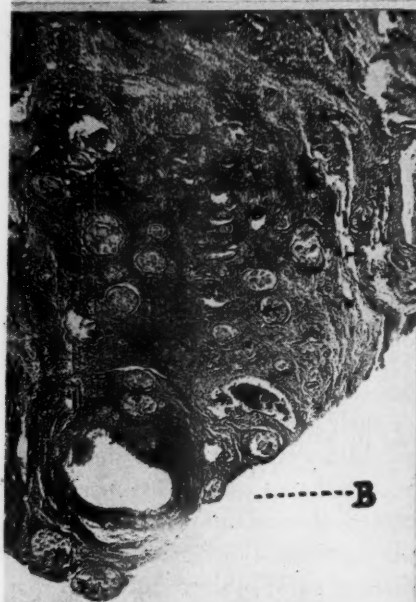
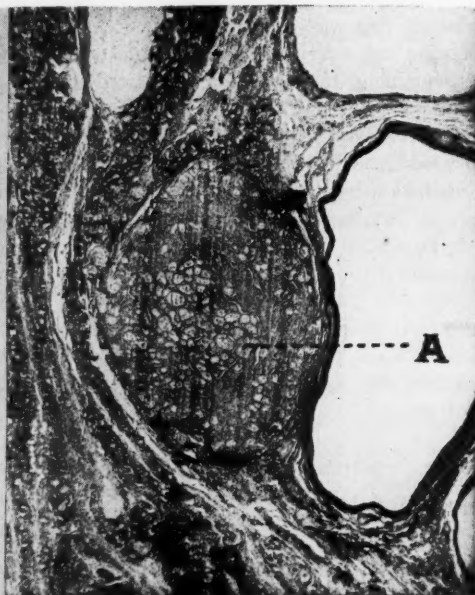


FIG. 3

FIG. 4

FIG. 1.—Low power photomicrograph of ovary, that measures 2.5 cm. x 1.5 cm. x 1.3 cm., showing (A) small granulosa cell tumor, 3 mm. in diameter. (B) Scattered collections of granulosa cells.

FIG. 2.—Higher magnification of (A) in Figure 1, showing the granulosa cell tumor.

FIG. 3.—Higher magnification of (B) in Figure 1, showing the scattered collections of granulosa cells near a follicle.

FIG. 4.—High power photomicrograph of granulosa cell tumor (A) in Figures 1 and 2, showing the folliculoid arrangement of the cells, swollen and clear due to lipoid deposition.

cases, superficially, was not unlike the one herein reported; in fact the slides (ovary with the small granulosa cell tumor) in the case here reported showed interstitial cells in the ovary, a finding usually associated with tumors of epithelial cells of male origin. Nelson Henderson,⁶ in his study of 21 granulosa cell tumors, noted many variations in the behavior of these growths, and the statement of Novak¹¹ that some cases of biologic activity, such as precocity, are not due to granulosa cell tumors, but may be the result of some disturbance of the pituitary or adrenals, is further evidence of the diagnostic complexities of the dysontogenetic group of neoplasms.

The syndrome of the tumor herewith presented does not follow the pattern of any previously reported case. This does not mean that none exist. They do not come to our attention because we have never suspected them and so have not looked for them, probably because they occur in a normal-sized ovary. I have been interested in tumors occurring in normal-sized ovaries; a paper on this subject is now in the process of publication (*Am. Jour. Obst. & Gynec.*) (published in *Am. Jour. Obst. & Gynec.* Vol. 51, No. 2, Feb. 1946, p. 246.) which shows that if the suspicion of a neoplasm in a normal-sized ovary is kept in mind, some of them can be detected at operation by careful examination, which includes inspection, palpation, puncture and even incision of the ovary during operation. With this in mind, a special effort has been made to detect these neoplasms at every operation where an abdomen is opened and the ovaries are able to be examined. Because of this interest in tumors in normal-sized ovaries, seven neoplasms were discovered in apparently normal ovaries during the past three years, among them the granulosa cell tumor herein reported. It is possible that a granulosa cell tumor of this particular type could be the basis of some cases of functional bleeding. There are patients with so-called functional bleeding that do not fit into any prescribed category and do not respond to the theoretic plan of treatment adapted to correct certain physiologic endocrine imbalances. They do not come to operation as a rule because no evident pathology is found by clinical examination. The case herein presented was designated dysfunctional bleeding for nine years before its true nature was learned. Some cases of functional bleeding that do not respond to treatment are very apt to end up in artificial castration either by roentgen ray or radium, seldom by operation, so that no evidence of their true nature is ever obtained. The lesion in those patients with bleeding from a small granulosa cell tumor that might come to operation for some other reason could very easily be missed in the pathologic examination, and these cases would, therefore, probably be classified dysfunctional bleeding.

The very small granulosa cell tumor herein presented behaves in a general way like an ordinary granulosa cell tumor, but there are a number of differences, so that the entire syndrome may be a new one, perhaps a distinct type of granulosa cell tumor. Its histopathology is the same as an ordinary granulosa cell tumor; it causes abnormal bleeding; and a cure can be effected by its removal—characteristics common to the ordinary granulosa cell tumor. But it is different in that it is so minute and has not distorted or changed the size of the ovary, after nine years of activity. More of these cases of a midget granulosa

cell tumor syndrome may be discovered if such a possibility is remembered and search made for them. In some cases of intractable functional bleeding not traceable to any apparent cause, it might be a good plan to perform a celiotomy first instead of artificial castration by roentgen ray or radium, in order to examine the ovaries in search of such a tumor.

SUMMARY AND CONCLUSIONS

A minute granulosa cell tumor, three millimeters in diameter, was found in a woman 23 years old, which produced abnormal vaginal bleeding ever since her menarche, nine years previously. She was cured by the removal of a normal-sized ovary that harbored the neoplasm, and her menses have remained normal since the operation four years ago.

Because of the peculiar symptom of abnormal vaginal bleeding for nine years, without apparent growth of the minute tumor, it is possible that we are dealing with a new variety of granulosa cell tumor. The syndrome of this "midgert granulosa cell tumor" could be the basis of some of the unexplained cases of so-called functional bleeding.

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STREPTOCOCCUS VIRIDANS SEPTICEMIA FROM VEGETATIONS IN FEMORAL ARTERIOVENOUS ANEURYSM

REPORT OF A CASE CURED BY SURGICAL EXCISION OF THE ANEURYSM

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SUBACUTE *Streptococcus viridans* septicemia is a common complication of valvular heart disease. It also occurs frequently in congenital heart disease. Less commonly it results from vegetations within extracardiac arteriovenous communications. Until recently subacute bacterial endocarditis was almost invariably fatal though at the present time it appears that intensive and prolonged treatment with penicillin yields rather favorable results. Since the valvular pathology still exists, however, there remains the hazard of a recurrence of the same process. When the disease results from congenital heart disorder the problem of treatment has been much the same as in those cases arising from valvular heart disease. An exception is that group of cases in which the vegetations occur in some congenital fistula near the heart which can be extirpated surgically, for example, instances of vegetations in a patent ductus arteriosus. Since the first surgical cure, reported by Touroff and Vesell,¹ in 1940, it has been apparent that the source of the bacteriemia can be removed by surgery and a permanent cure obtained. Similarly, when vegetations within extracardiac arteriovenous communications give rise to *Streptococcus viridans* septicemia a permanent cure can be effected by excision of the aneurysm. Although a number of instances of such bacteriemia associated with arteriovenous aneurysm have occasionally been observed in the past, the first surgical cure was reported by Hamman and Rienhoff.² Their patient was a 35-year-old man, with an arteriovenous aneurysm of the external iliac vessels which had resulted from a rifle injury 17 years before. In 1942 Touroff, Lande and Kroop³ recorded a second case, a 26-year-old man who had an arteriovenous and sacular aneurysm of the profunda femoris vessels resulting from a gunshot wound nine years previously. More recently, a third case has been reported by Lipton and Miller,⁴ that of a Negro, age 27, who had a femoral arteriovenous aneurysm of 15 years duration, which also had resulted from an accidental gunshot injury. No other examples of cure of *Streptococcus viridans* septicemia by surgical removal of an arteriovenous aneurysm have come to our attention.

Acquired arteriovenous aneurysms are relatively uncommon in peacetimes, but occur quite frequently in time of war. It is not unlikely that the great increase in the number of such fistulae brought about by the present war may result in more cases of bacteriemia from infected vegetations within these lesions. Because of this and because of the small number of cases reported with

surgical cure, it is felt advisable again to call attention to this syndrome by reporting in some detail a patient in whom such a cure was effected.

Case Report.—The patient, a 26-year-old soldier, had enjoyed good health in the past, had had no serious illness except for three attacks of malarial fever during the past 14 months, no operations, and review of his systems was not remarkable except for recurrent attacks of tonsillitis. His past cardiovascular history was entirely normal. He was inducted into the Army in March, 1943. On December 21, 1944, in Leyte, after 18 months of duty in the Southwest Pacific Area, he received penetrating grenade fragment injuries in the right thigh, left arm, left chest, and left thigh from enemy action. There was considerable bleeding from the right thigh wound, but it was controlled with compression bandage. His wounds were débrided at a Surgical Portable Hospital and he was evacuated through channels to a numbered General Hospital. Here, about the 18th of January, he called the attention of the attending medical officer to a purring sensation in the right thigh which he had first noted the third day after injury. The classical signs of arteriovenous aneurysm were found. He was returned by air to the Zone of Interior and was admitted to the Vascular Center at the Mayo General Hospital on February 11, 1945.

The wounds had healed without difficulty. He had no symptoms except for a purring sensation in the right thigh and a little numbness along the mesial aspect of his knee. He complained of no edema, coldness, cyanosis, pain or weakness in the right lower extremity. Physical examination revealed the generalized yellowish color of the skin, commonly seen in patients who have had prolonged atabrine therapy. His sclerae were normal in color. There was nothing remarkable about the general examination. There was no tortuosity or thickening of the peripheral arteries, no evidence of cardiac enlargement; his heart sounds were normal and there were no murmurs. There was an abnormal pulsation over the course of the femoral vessels in the proximal third of the thigh associated with a continuous thrill and a loud continuous bruit which could be heard down to the knee and up into the right lower quadrant of the abdomen. The thrill and bruit could be obliterated by direct pressure over the femoral vessels about 15 centimeters below the inguinal ligament. With such compression the pulse rate slowed from 76 to 52 per minute and the blood pressure rose from 124/64 to 138/86. After atropinization the blood pressure changes with compression were of the same magnitude but the pulse rate decreased only eight per minute. The dorsal pedal and posterior tibial pulses were normal in both feet as was the venous filling time. In a room at 22° C. the skin temperature of the right toes varied from 19° to 20° and of the left toes from 21° to 21.5°. Reactive hyperemia, after five minutes of total arterial occlusion, and with the fistula completely compressed by digital pressure, began in the toes in 20 seconds and was complete and full in the right foot in 90 seconds. EKG was normal except for a QRS complex of 0.12 seconds duration. Roentgenograms showed no cardiac enlargement, the frontal area being 146 square cm. compared to a predicted frontal area of 143 square cm. for a man of his height and weight. The impression was held that he had a femoral arteriovenous aneurysm with collateral circulation adequate for surgical extirpation.

On March 1, 1945 the patient developed chills and fever which recurred in 48 hours and the diagnosis of malaria was confirmed by a blood smear which was positive for *Plasmodium vivax*. The chills and fever were readily controlled by atabrine therapy, the blood smears became negative and he left the hospital on furlough. He returned on April 5, 1945. He had had a recurrence of chills and fever associated with a sore throat shortly after he left the hospital and a week later had developed some abdominal soreness and a persistent mild diarrhea. Thinking that he had a recurrence of malaria he had taken atabrine but his symptoms had not been relieved. He had been confined to bed most of the three weeks of his furlough and had lost 16 pounds in weight. He had some anorexia. On admission to the hospital, there was some tenderness in the region of the transverse colon and his spleen was just palpable. His temperature was 102° F. on admission and

SEPTICEMIA FROM ANEURYSM

not higher than 99.2° F. during the next three days. Stool examinations revealed the ova of hook worm and *Endamoebae*. Appropriate treatment for these parasites resulted in prompt disappearance of his intestinal symptoms. Repeated blood smears were negative for *Plasmodia*. He continued to have fever (Fig. 1).

On April 11, 1945, he had a chill and a temperature rise to 100.3° F. The next day it rose to 102.4° F. Atabrine was discontinued on April 14, 1945, no malarial parasites having been found in blood smears since March 3, 1945. On April 16, 1945 he had a severe chill followed by a rise in temperature to 102.4° F. Three days later he had another chill with a temperature of 101.3° F. He complained of some pain and tenderness

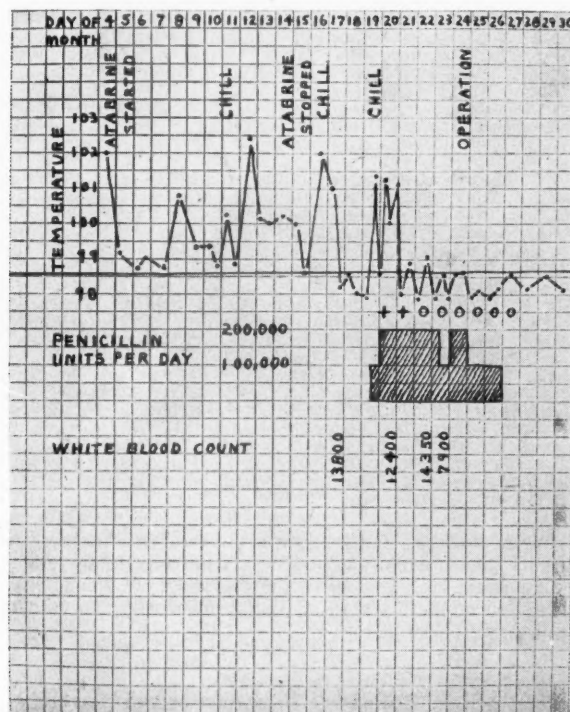


FIG. 1.—Temperature chart of patient preceding and following operation. The symbol + signifies a positive blood culture on the date indicated; the symbol O, a negative blood culture.

over the sternum and was dyspneic and orthopneic. Within a few hours the chest pain shifted laterally, being localized in the left fourth interspace in the anterior axillary line. There was marked tenderness here. For the first time a soft blowing nontransmitted systolic murmur was heard in the third interspace to the left of the sternum. The first heart sound was roughened and the apical impulse was displaced 3 cm. to the left of the midclavicular line. There were absent breath sounds, crepitant râles, and marked dullness to percussion over the left lower lobe posteriorly. Clinically, the findings suggested pulmonary embolism. The temperature was 101.2° F., the pulse 120, and respirations 20. Roentgenograms revealed increase in density obliterating the left lower lung field—findings compatible with a diagnosis of pulmonary infarction. The frontal cardiac area had increased from 146 sq. cm. on February 13, to 168 sq. cm. on April 5. On April 20, though difficult to measure because of the lung pathology, it was in the neighborhood of

174 sq. cm. EKG on the same day showed sinus tachycardia with slight slurring of QRS in the third lead and with a QRS complex of from 0.10 to 0.11 seconds duration.

The persistence of intermittent chills and fever, together with clinical and roentgenographic signs suggestive of pulmonary embolism, pointed to a diagnosis of septicemia, and it seemed most likely that the source was from infected vegetations within his arteriovenous aneurysm. A blood culture taken on the following day (April 20) was reported 24 hours later as positive for *Streptococcus viridans*. The white blood count was 12,400, with 28 per cent lymphocytes. Hemoglobin was 11.9 grams, prothrombin time was 30 seconds, and the hematocrit was 36. There was no increase in tenderness on pressure over the arteriovenous aneurysm and no petechiae were seen.

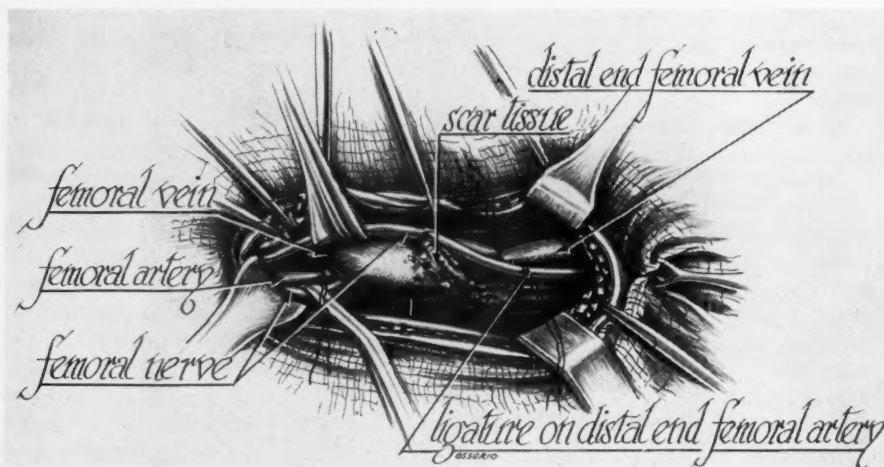


FIG. 2.—Drawing made from photograph of aneurysm taken during operation. The artery and vein have been ligated proximally and distally to the site of the fistula. The dilatation of the vein and the scarring in the region of the aneurysm are shown as well as the close association of the branches of the femoral nerve to the aneurysm. (Drawing by Cpl. Alfonso Ossario.)

The patient was acutely ill and his expression one of grave apprehension. He was given dilaudid for relief of his chest pain. Penicillin therapy was instituted on April 19 by the intramuscular injection of 25,000 units of penicillin sodium every three hours for three days, followed by 12,500 units every three hours for an additional three days. A second blood culture taken on April 21 was again positive for *Streptococcus viridans*. Subsequent blood cultures repeated on six consecutive days showed no growth of organisms. Coincident with the negative blood culture the patient became afebrile and free of chills. The white blood count dropped to 7,900, and his condition was much improved. Penicillin had apparently rendered the blood stream sterile in a period of less than 48 hours. On April 24, immediately after the intravenous injection of 100,000 units of penicillin, the patient was operated upon.

Operation.—Under spinal anesthesia, a longitudinal incision, about 12 cm. in length, was made over the course of the femoral vessels, beginning about 6 cm. below the inguinal fold. The fascia was divided and the sartorius muscle was retracted. There was a great deal of scarring in the region of the vessels. The femoral artery and vein were isolated above and below the fistula. The femoral vein was dilated to a diameter of about 2 cm. and the artery was about normal in size. A continuous thrill was present. The saphenous and the femoral nerves which were adherent to the vessels were dissected free without injury (Fig. 2). The artery and vein were divided above and below the fistula after



A

FIG. 3.—Kodachrome photographs of specimen removed at operation. The numerous vegetations along the margins of the fistula are shown. (A) A view of the arterial side. (B) A view of the venous side of the fistula.



B

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transfixing the stumps with silk. The wound was closed in layers with interrupted silk sutures. The patient's condition remained good during the operation.

Pathologic Examination.—Examination of the excised specimen revealed a large fistula, almost 1.5 cm. in diameter, between the artery and vein. The margins of the fistula were studded with small and minute vegetations (Fig. 3). Cultures taken directly from these vegetations, at a time when his blood cultures were negative, revealed a heavy growth of *Streptococcus viridans*. On microscopic examination these vegetations were literally studded with cocci (Fig. 4).

The patient's postoperative course was uneventful. He remained afebrile. The temperature and color of his right leg were normal. The bruit and thrill were no longer present. His pulse and blood pressure were normal. He was allowed out of bed on the 4th day. For some days he had a pulling sensation in his left chest on deep inspiration,



FIG. 4.—Photomicrograph of a portion of the specimen showing two bacteria-studded vegetations. (H. and E. stain.) On high power examination the dark staining areas are seen to be a mass of cocci. Culture of such vegetations as these yielded a pure growth of *Streptococcus viridans*.

but this discomfort rapidly disappeared. The dyspnea and orthopnea were gone. The signs of infarction in the left lower lobe gradually disappeared and six weeks after operation were absent by both radiologic and clinical examination. The size of his heart returned to normal (Fig. 5). The patient had at first a little edema of his leg after prolonged dependency. When examined on July 5 he stated that he had had no edema at all for a week. He was wearing an elastic stocking. He had no symptoms, except fatigue of his right lower extremity. On walking a distance of a half mile he would have a sense of fatigue in his calf. His feet showed no abnormal color changes. The posterior tibial and dorsal pedal pulses were normal on the left and were present, though reduced in volume, on the right. In a room at 25.5° C. there was no difference in the temperature of the toes of the right and left foot, all of the toes varying between 29 and 30° C. Oscillometry in the distal thigh was 2.5 at 70 mm. right, 6 at 120 left. In the calf it was 3 at 60 right, 7.5 at 90 left, and in the ankle it was 2 at 70 right and 5 at 80 left. His pulse was 56 and his blood pressure 128/70.

By the end of July the patient stated that he had practically no complaints at all. He had not worn elastic support for three weeks and had had no edema. He said that he

could walk an indefinite distance. After walking about a mile and a quarter he had a mild sense of tightness in his right calf, but the discomfort was not great enough to make him cease walking. There had been no recurrence of fever, chills nor of pulmonary or cardiac symptoms. He appeared to be in excellent general health.

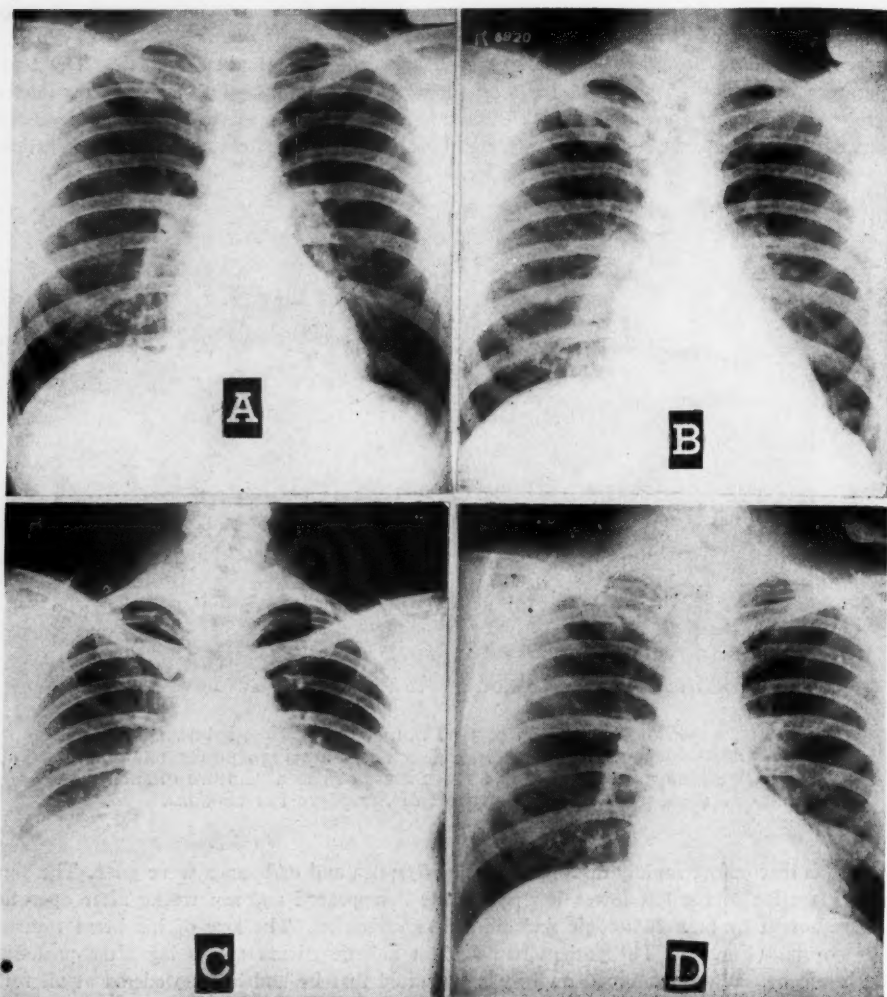


FIG. 5.—Roentgenograms showing change in heart size and the evidence of pulmonary infarction. (A) Roentgenogram taken February 13, 1945. Heart size is normal, the frontal cardiac area being 146 sq. cm. Predicted frontal area for a man of the patient's height and weight is 143 sq. cm. The method of Ungeleider and Gubner was used in computing heart size. (B) Roentgenogram taken March 1, 1945. Heart size has increased. Frontal cardiac area 168 sq. cm., 17 per cent above normal. (C) Roentgenogram taken April 23, 1945. The increased density in left lower lung field from pulmonary infarction is shown. Heart size difficult to estimate because of lung pathology and elevation of diaphragm. (D) Roentgenogram taken June 4, 1945. Postoperatively, the lung field has cleared and the heart size has returned to normal.

DISCUSSION.—It is a well-known fact that transient *Streptococcus viridans* bacteriemia occurs not rarely during upper respiratory or sinus infections and following extraction of infected teeth. Presumably such transient bacteriemia is the original source of infection in cases of subacute bacterial endocarditis and in instances similar to the case reported. It is of interest that our patient gave a history of recurrent attacks of tonsillitis since childhood and that he had had an attack of tonsillitis and pharyngitis, associated with chills and fever approximately a month prior to the diagnosis of septicemia. It is possible that this may have resulted in infected vegetations within his arteriovenous aneurysm.

The case reported is of considerable interest in regard to multiplicity of diseases from which the patient suffered during the course of his hospitalization. In addition to an attack of tonsillitis and pharyngitis, and the subsequently proved *Streptococcus viridans* septicemia, he had malarial fever, hook worm and *Endamoebae* in his stools. The fact that this patient had had recurrent episodes of malarial fever did not, however, delay long the diagnosis of *Streptococcus viridans* septicemia. The severe chills, the fever, the signs and symptoms of pulmonary infarction, the positive blood cultures and the presence of an arteriovenous aneurysm made the diagnosis relatively easy. The rapid increase in cardiac size is very likely directly the result of the altered circulatory dynamics consequent to the presence of a large femoral arteriovenous aneurysm. In other patients with similar lesions, rather marked increase in heart size has not been uncommon during the period of observation prior to excision of the aneurysm.

The case reported serves as another example of the necessity of bearing in mind the presence of arteriovenous aneurysm when looking for the source of infection in instances of *Streptococcus viridans* septicemia. It also exemplifies the dramatic cure which can be achieved in such instances by surgical removal of the aneurysm. Our patient was treated for a period of six days with penicillin, which apparently rendered the blood stream sterile prior to operation. That a permanent cure had not necessarily been obtained by this brief period of treatment is evident from the fact that the vegetations within the aneurysm yielded a heavy growth of *Streptococcus viridans*.

SUMMARY

A case is added to the three previously recorded in the literature of instances of cure of *Streptococcus viridans* septicemia associated with infected vegetations within peripheral arteriovenous aneurysms by surgical excision of the lesion.

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THE INFLUENCE OF A SPECIAL HIGH PROTEIN DIET ON PROTEIN REGENERATION IN THE SURGICAL PATIENT*

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IT HAS BEEN ESTABLISHED^{1, 2, 3} that negative nitrogen balance usually occurs in the postoperative patient. This has been correlated with loss of weight, prolonged wound healing, and extended convalescence.^{4, 5} During recent months a great deal of investigation has been done in an attempt to institute positive nitrogen balance in these patients. The work of Co Tui, Elman, Rasmussen, particularly among others, is to be noted.⁶⁻¹⁰ It is significant that amino-acid mixtures, plasma, and whole blood transfusions have been emphasized in these studies; the value of these we leave unquestioned. Most of the emphasis on protein replacement therapy in the surgical patient has centered around a substance that can be given safely by the intravenous route. In the studies reported here, we have thought it desirable to shift this emphasis to a diet that could be given orally, and to determine the value of an inexpensive protein material which can be made readily available to surgical patients. Despite the unsettled state of controversy that has revolved around the question of whether or not administered protein is assimilated during the catabolic phase which follows early after traumatic injury or surgical operation, we have supplied this diet to our patients soon after surgical operation.

MATERIAL AND METHODS

Suitable surgical patients were selected; the dietary period was started on the 3rd to the 20th postoperative day. Nine patients, fully studied, are considered in this report, and clinical summaries of several illustrative cases are given.

A diet was made up as follows: 150 Gm. of dehydrate beef and liver protein mixture,[†] 150 Gm. of powdered whole milk, 50 Gm. of corn oil, 150 Gm. of sucrose, 150 Gm. of dextrimaltose, 35 Gm. of chocolate, 1,000 cc. of water (plus vitamins, especially A, B, C, and D, and Iron). This allowed a total intake of at least 3,000 calories for each 24-hour period.

The diet was administered in liquid form containing the insoluble materials

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† "Valentine High Protein Mixture" generously supplied by The Valentine's Meat Juice Company, Richmond, Va.

that had been put into a finely divided suspension by rapid stirring in a Mix-Master stirring machine. Since there was a tendency for this suspension to settle out with standing it was shaken before each feeding. In three cases tube feeding was resorted to during the first two or three days and thereafter the diet was taken readily by mouth. Frequent feedings throughout each 24-hour period were employed.

Blood volume, total and fractional plasma protein, hematocrit, and hemoglobin determinations were carried out at the beginning of each experiment, three or four days thereafter, and again at the end of the experimental period. The nitrogen content of the diet per cubic centimeter was determined and the protein intake for each day calculated from the volume administered. Daily urinary and fecal nitrogen excretion was determined and the nitrogen balance calculated. Blood volume studies allowed total circulating plasma and protein hemoglobin to be estimated. Each patient was studied for at least seven days.

DISCUSSION OF RESULTS

Two cases (L. D., Chart 1; and T. H., Chart 2) of partial gastric resection and perforated peptic ulcer were given the diet starting on the 4th and 9th postoperative day, respectively. Both of these cases were uncomplicated and noninfective and both completed the feeding schedule without incident. In the case of L. D., the average nitrogen intake 24 hours was 23.5 Gm., with the average daily excretion being 19.7 Gm. of nitrogen. Studies of this case over an eight-day period revealed 81 Gm. of hemoglobin, and 39 Gm. of plasma protein formed to approximately 80 Gm. of tissue protein laid down. Average daily nitrogen excretion in the case of L. D. was very high as compared with the case of T. H. who was given the diet over a seven-day period. The latter case manifested an average daily nitrogen intake of 23.2 Gm., with an average daily excretion of 16.5 Gm. of nitrogen. Protein regeneration, however, was similar in distribution being of the order of 102 Gm. of hemoglobin, 44 Gm. of plasma protein, and with 160 Gm. of tissue protein being laid down. In respect to plasma protein formation, the case of T. H. showed the greatest gain in albumin fraction. It is to be noted that in the latter case, plasma protein concentration remained fairly low as shown by the values of 5.69 Gm. protein per 100 cc. plasma to 5.52 Gm. protein per 100 cc. plasma; yet the total circulating plasma protein gained considerably (Table I). Case summaries of both of these patients are presented below.

In the case where most intolerance to the diet was anticipated, that of G. B., (Chart 3) an abdominal gunshot wound with resection of eight feet of small bowel (ileum), the least difficulty was encountered. The diet was instituted on the 7th postoperative day and maintained for ten days. This patient responded exceedingly well, as shown by the regeneration of 70 Gm. of hemoglobin, 28 Gm. of plasma protein, and approximately 614 Gm. of tissue protein. Nitrogen retention in this case was over half of the calculated intake and demonstrates in this patient a remarkable power of assimilation in spite of the large amount of small bowel resected (see case summary).

Infective postoperative cases presented the greatest intolerance to the diet. These patients exhibited a great deal of anorexia, nausea, and vomiting, and only three cases are included where complete studies were made. These patients were given the diet by way of a Levine tube during the first 24 to 36 hours of feeding.

PRESENTATION OF CASES

Case L. D. (Chart I): This 34-year-old colored male was admitted to St. Philip Hospital, March 2, 1944, with a chief complaint of severe progressive abdominal pain of 11 hours duration. The patient was quite nauseated but did not vomit.

CHART I

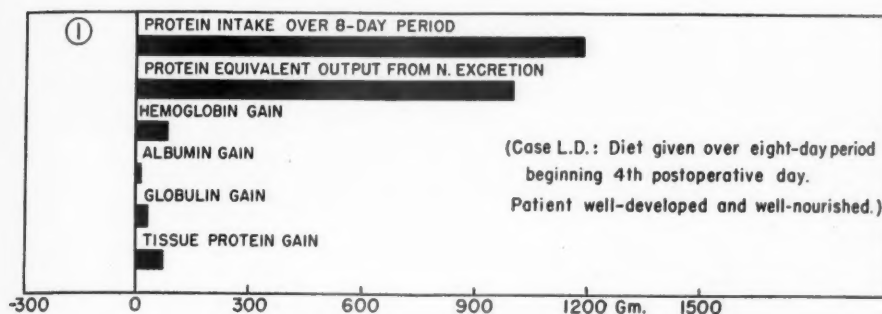


CHART I.—Case L. D.: Nitrogen Balance Chart.

The diet was given over an eight-day period beginning on the 4th postoperative day. The patient was well-developed and well-nourished.

Physical examination revealed the abdominal wall rigid, especially over both upper quadrants. The patient was immediately taken to the operating room and, under spinal anesthesia, a right rectus incision was made. A moderate amount of creamy, thick, light yellow material was encountered. No odor to this material was apparent. The stomach was moderately distended, and a 2x2 cm. area of induration was found in the anterior, prepyloric region which was bound to the liver by fresh adhesions. Exploration revealed a perforation, of about 3 mm. in diameter, within this area. The ulcer area was partially excised and then closed with two rows of No. 1 B. S. S. The omentum was then caught up over the suture line and a third row of stitches was placed. The upper portion of the abdomen was then washed with warm saline and eight grams of mixed sulfonamide powder dusted over the area. The abdomen was then closed. The patient completed the operation in good postoperative condition. Laboratory studies on admission revealed the following: Hb. 73 per cent; W. B. C. 13,150, polys. 88 per cent. Urinalysis was essentially negative. On the first postoperative day the Hb. 65 per cent; W. B. C. 10,500, polys. 70 per cent. On the 12th postoperative day the Hb. 82 per cent; W. B. C. 8,200, polys. 71 per cent. Two blood transfusions of 500 cc. each were given on the second postoperative day. The patient's temperature spiked on two occasions to 103° F., but began to recede on March 6, and thereafter varied between normal and a low grade fever until March 20. Chest roentgenograms during this interval revealed densities compatible with postoperative atelectasis in the right lower lobe. The condition of the patient, clinically, was good and severe infection did not appear to be present. The patient was given a special experimental diet over an eight-day period beginning on the 4th postoperative day (March 6). Nitrogen balance studies were carried out during the feeding period and the results tabulated. The patient was discharged March 23, 1934, and followed by the Out-patient Clinic.

TABLE I
SUMMARY OF RESULTS

Case No.	Prot. Intake /Kilo. /24hr. take Gm.	N. In. Gm.	N. Out. put Gm.	Blood Volume		Plasma Volume		Plasma Albumin		Plasma /100 Cc.		Total Plasma Albumin		Alb. Gain		Plasma Globulin /100 Cc.		Total Plasma Globulin		Average Hematocrit Reading		Hemoglobin /100 Cc. Blood		Total Hemoglobin globin	Hemo. Gain Gm.
				Init.	Final	Init.	Final	Init.	Final	Init.	Final	Init.	Final	Init.	Final	Init.	Final	Init.	Final	Init.	Final	Init.	Final		
				Gm.	Cc.	Gm.	Cc.	Gm.	Cc.	Gm.	Cc.	Gm.	Cc.	Gm.	Cc.	Gm.	Cc.	Gm.	Cc.	Gm.	Cc.	Gm.	Cc.		
L. D.	8-day period	2.76	187	147	5,187	5,276	2,826	2,755	3.50	3.98	99	110	11	2.95	4.0	83	112	29	45.1	47.8	14.4	15.7	747	828	81
T. H.	7-day period	2.39	162	116	4,798	6,000	3,242	4,125	3.49	3.66	113	151	38	2.12	1.86	71	77	6	30.5	31.3	9.36	9.18	449	551	102
G. B.	10-day period	2.44	243	131	4,320	4,913	2,731	2,992	3.99	4.17	109	125	16	2.52	2.68	69	80	11	36.7	39.1	11.2	11.3	484	554	70
J. H.	1st 5 days	3.77	119	45	4,633	4,874	3,068	3,184	3.75	4.0	115	128	13	2.68	2.66	82	85	3	33.8	34.7	10.8	11.0	492	538	46
J. H.	2nd 5 days	3.77	108	57	4,874	4,621	3,184	3,074	4.0	3.86	128	119	-9	2.66	3.13	85	96	11	34.7	33.5	11.0	10.6	538	490	-48
B. A.	7-day period	2.36	162	76	5,982	4,623	3,569	3,292	2.64	3.29	94	108	14	3.32	3.68	118	121	3	40.3	38.8	13	12.2	778	564	-214
M. P.	7-day period	2.99	184	51	3,349	3,594	2,472	2,543	3.66	3.24	90	83	-8	3.153	3.40	87	86	-1	22.9	28.9	6.3	8.34	211	300	89
C. T.	10-day period	3.33	249	86	3,342	3,692	2,325	2,428	3.36	3.37	78	82	4	5.135	5.05	124	123	-1	34.4	34.2	11.7	11.8	391	436	45
J. W.	8-day period	3.5	214	104	3,959	4,140	2,146	2,153	4.31	3.84	92	83	-9	3.04	3.58	65	77	12	45.8	48.0	14.9	17.1	593	708	115

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Case T. H. (Chart 2): This 43-year-old colored male was admitted to the hospital, February 8, 1944, following a profuse gastric hemorrhage. His chief complaint was hematemesis and tarry stools. History of the present illness dated to four years before at which time the patient began altering his diet because of indigestion. Following a night of beer drinking, February 5, he had a severe diarrhea. A large dose of Epsom salts was taken. On February 7, his stools were tarry black. On the night of admission, he experienced an episode of faintness and sweating. He vomited about one-half cupful of bloody clots and coffee ground-like material.

CHART 2

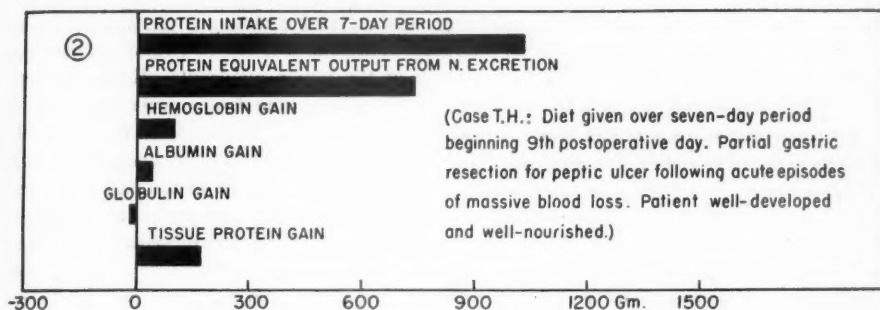


CHART 2.—Case T. H.: Nitrogen Balance Chart.

The diet was given over a seven-day period beginning on the 9th postoperative day. Operation was partial gastric resection for peptic ulcer following acute episodes of massive blood loss. The patient was well-developed and well-nourished.

CHART 3

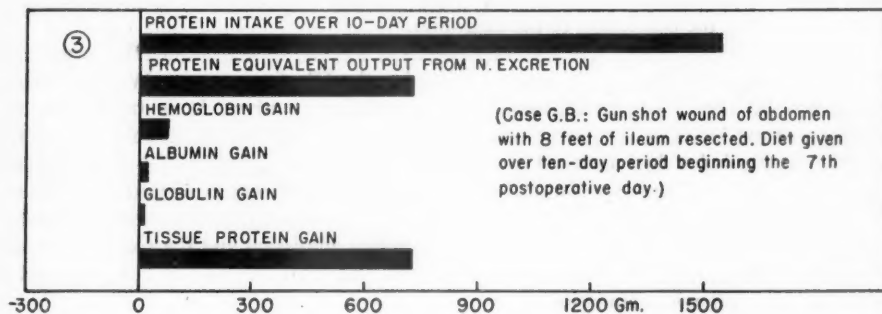


CHART 3.—Case G. B.: Nitrogen Balance Chart.

The injury was a gunshot wound of the abdomen. At operation eight feet of ileum was resected. The diet was given over a ten-day period starting on the 7th postoperative day.

Physical examination revealed a well-developed and well-nourished, lanky, colored male. Abdominal examination elicited no pathologic findings. The impression on admission was bleeding peptic ulcer with severe hemorrhagic anemia. The patient was transferred from medicine to surgery service February 12, and following a gastric irrigation, a modified Billroth-I anastomosis was performed under general anesthesia. Resection of the ulcer-bearing area was carried out. A Wangensteen tube was left in place postoperatively until February 15.

Laboratory findings were as follows: On admission the Hb. 20 per cent; W. B. C.

19,950, polys. 84 per cent. Urinalysis revealed 5 W. B. C./H. P. F.; otherwise it was with normal limits. On February 12, the Hb. was 52 per cent. A Sippy diet regimen was carried out until February 21, at which time a special experimental diet was given for one week. Results are tabulated in Table I. The patient left the hospital seven days after completion of the dietary regimen in a much improved condition.

Case G. B. (Chart 3). This 16-year-old colored male was admitted to St. Philip Hospital emergency room, March 14, 1944, with a chief complaint of gunshot (.22-caliber) wound of the abdomen. The shooting occurred three hours prior to admission. He stated that vomiting occurred during this interval. No blood was present in the vomitus. Only slight external hemorrhage from the wound was evident. Physical examination revealed a well-developed and well-nourished colored male lying in bed in moderate pain. The patient was slow to respond to questioning. Generalized abdominal tenderness without apparent localization was present. Involuntary spasm was elicited. Slight dullness was found in both flanks with a tympanitic sound in the upper quadrants. Some distention was found and peristaltic sounds were audible. A small wound of entrance was present lateral to and 5 cm. above the anterior iliac spine. No wound of exit could be found. The patient was immediately prepared for operation. Under ether-oxygen anesthesia, a left rectus incision was made. After the peritoneum was opened, the abdominal cavity was found to be filled with a large amount of fresh blood. There were multiple perforations of the ileum and a few perforations of the jejunum. Part of the mesentery was badly punctured causing the corresponding ileum to have a dusky appearance. The smaller openings in the intestine were repaired with chromic catgut No. 0000 and reinforced with No. c silk. The bleeders in the mesentery were controlled. Eight feet of the ileum had to be resected because of injury to the corresponding mesentery. An open end-to-end anastomosis was done by a continuous running stitch of chromic catgut No. 0000. A Connell suture was taken in another location. The latter was reinforced by Cushing sutures. The mesentery was approximated with chromic catgut No. 0. The abdominal cavity was then irrigated with warm saline. Six grams of mixed sulfonamide powder was placed into the abdominal cavity. The abdomen was then closed. The patient's condition was good at the conclusion of the operation.

Laboratory studies revealed the following: On the day of admission Hb. 80 per cent before operation. On the second postoperative day the Hb. 63 per cent; W. B. C. 6,400, polys. 67 per cent. The urinalysis was essentially negative. It is noted that the patient's icteric index on March 15 was 55 units and jaundice was noticeable. On March 20, the icteric index had dropped to 23 units. Six days following the operation the patient was placed on an experimental dietary regimen which was continued for ten days. Nitrogen balance studies were carried out during this interval and the results tabulated. The patient received 1,250 cc. of whole blood between admission and the second postoperative day. The patient's hospital course was satisfactory and he was discharged April 3, 1944, 20 days following admission.

Case J. H. (Chart 4): This 58-year-old colored female was referred to the hospital emergency service, April 11, 1944, because of a large, left inguinal hernia which was incarcerated. History of her present illness dates back to ten years ago, at which time the patient noticed a small, intermittent swelling in the left groin. This swelling became progressively larger but remained reducible. During the past two years the hernia had occasionally become irreducible for varying periods. Nausea and vomiting were frequently associated with these periods of irreducibility. On the morning of admission the patient suffered a sudden attack of lower abdominal pain following a tremendous swelling of the left inguinal region. The patient became very nauseated and vomiting occurred. Her physician referred the patient to St. Philip Hospital for treatment.

Physical examination revealed a well-developed, well-nourished obese female lying in bed in a semiconscious, restless state and apparently in moderate shock. Abdominal examination revealed slight rigidity with few audible peristaltic sounds. No masses were

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palpated except a very large, pendulous swelling in the left inguinal region. This mass was not reducible by continuous pressure. The patient was taken to the operating room and, under local infiltrative anesthesia, release of the incarcerated bowel with excision of the false skin sac followed by repair was done. The patient was returned to her room in fair postoperative condition.

Laboratory studies showed the following: On the day of admission, the Hb. 96 per cent; W. B. C. 17,850, polys. 90 per cent. Urinalysis revealed a trace of albumin with

CHART 4

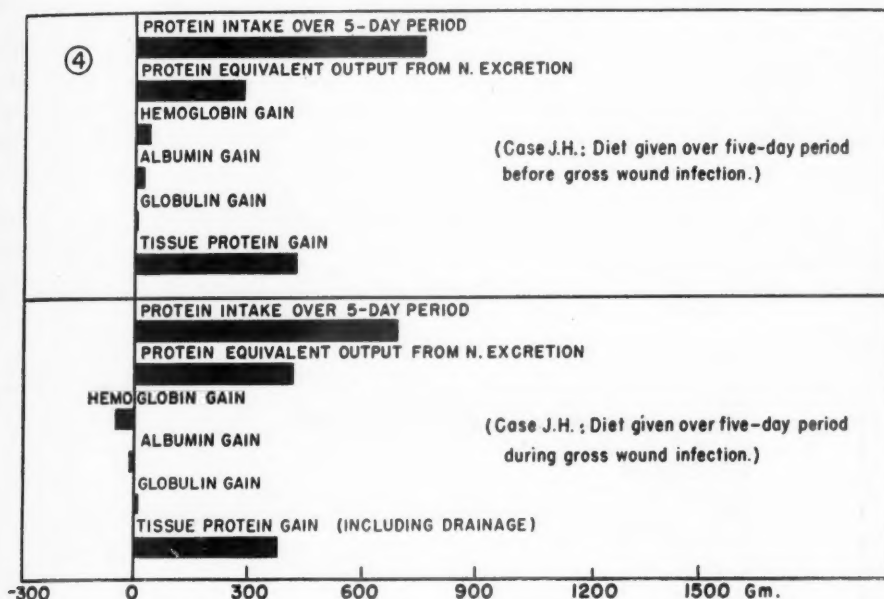


CHART 4.—Case J. H.: Nitrogen Balance Chart.

The diet was given for a five-day period preceding and during gross wound infection.

many granular casts, other determinations were within the normal range. On April 12, postoperatively the Hb. 71 per cent; W. B. C. 5,900; polys. 65 per cent. On May 2, the Hb. 62 per cent; W. B. C. 16,650, polys. 79 per cent. Subsequent urine examinations during the above period revealed no pathologic findings.

Following the operation, the patient had a low grade fever varying between 99° and 102° F. until April 21. Temperature at this time fell to within the normal range and only on three occasions reached 100° F. On May 1, 18 days postoperatively, her temperature spiked to 103° F. and continued to follow a septic course. Drainage from the local wound infection became more marked with the elevated temperature and systemic manifestations of gross wound infection were evident. An experimental dietary regimen was initiated April 26 and was continued until May 6. This included a five-day period when the wound infection was well localized and another five-day period when gross infection with spread and systemic reaction was present. Nitrogen balance and blood regeneration studies were followed and tabulated. Patient was finally discharged June 21, 1944, following healing.

Case M. P. (Chart 5): This 18-year-old white female was admitted to Gynecologic Service, June 14, 1944, with a chief complaint of vaginal bleeding of 21 days duration. The bleeding began as a normal period but increased in amount and persisted.

Physical examination revealed a pale, malnourished, asthenic patient. The spleen was palpable and hard. The veins of the fundus were quite tortuous. The uterus was somewhat enlarged and boggy with probable prolapse of the left ovary. Laboratory studies showed the Hb. 30 per cent; W. B. C. 7,000; and urinalysis revealed 8 W. B. C./H. P. F. The patient was treated with mocassin venom, iron, and two transfusions. Vaginal bleeding ceased. On June 22 the patient's temperature rose to 104° F. and sulfadiazine medication was given. Because of the continued fever, enlarged spleen, and anemia, the patient was transferred to the Medical Service. Blood studies disclosed nothing except an increased bleeding time of 23 minutes. Roentgenograms of the chest, routine agglutinations and blood cultures were repeatedly negative. The patient was placed upon an experimental dietary regimen July 7, and maintained for one week. Nitrogen balance and blood regeneration studies were carried out during this interval and tabulated. One week following completion of the experimental study the patient began to bleed again. She was proved to be *Bh*-negative, and difficulty was encountered in finding subsequent blood for transfusion. The patient was given a short course of radium therapy to stop the bleeding and was finally discharged in good condition.

COMMENT.—Nitrogen retention was good in all cases, averaging in some subjects over one-third of the nitrogen intake. It was interesting to note that where malnourishment and anemia were prominent factors as shown by the

CHART 5

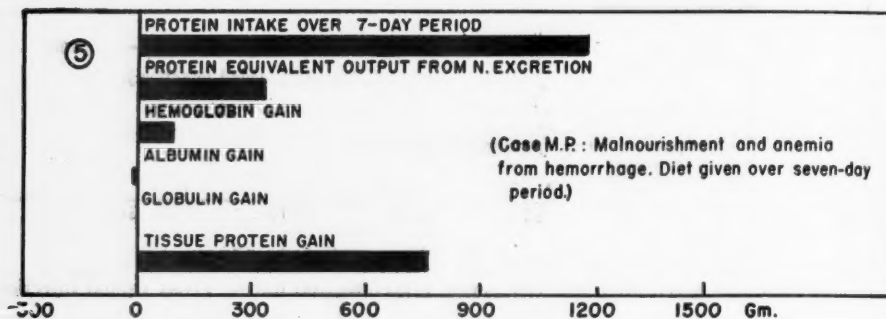


CHART 5.—Case M. P.: Nitrogen Balance Chart.

Patient was suffering from malnourishment and secondary anemia that resulted from hemorrhage. The diet was given over a seven-day period.

Cases of C. T. (Chart 6) and M. P. (Chart 5), hemoglobin, plasma protein, and tissue protein formation closely paralleled the results of Robscheitt-Robins¹² with hypoproteinemic dogs. That is, for every Gm. of plasma protein formed, two to four Gm. of hemoglobin and 10 to 30 Gm. of tissue protein were formed. Cases which appeared to be well-nourished, however, but in whom blood loss was a prominent factor used a greater percentage of the retained nitrogen for plasma protein and hemoglobin formation. This point is brought out by comparing the case of partial gastric resection which suffered acute episodes of bleeding just prior to operation (Case T. H.) with that of chronic depletion of body protein due to continued bleeding (Case M. P.) or continued wound drainage (Case C. T.). Both of these latter cases were asso-

PROTEIN DIET IN SURGICAL PATIENTS

ciated with inadequate food intake over a month's period of time before experimental diet was initiated.

Blood regeneration in cases where acute infection was present revealed suppression of hemoglobin formation even to the extent of hemoglobin loss. This occurred in spite of the fact that nitrogen retention was quite satisfactory.

CHART 6

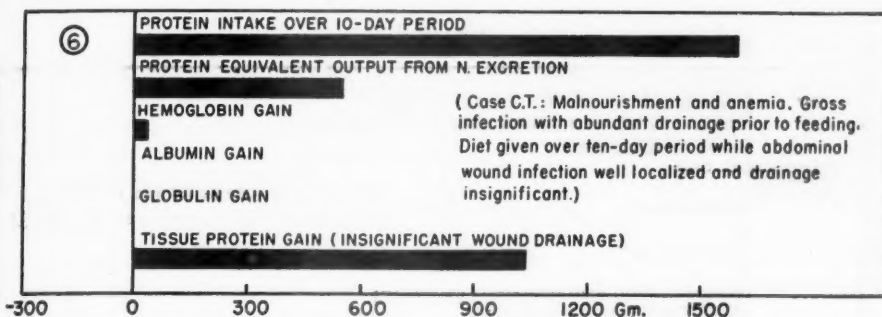


CHART 6.—Case C. T.: Nitrogen Balance Chart.

The patient suffered from malnourishment and anemia. There was gross wound infection with abundant drainage prior to feeding. The diet was given over a ten-day period when abdomen wound infection was well localized and drainage not significant. Nitrogen balance studies were made during this period.

CHART 7

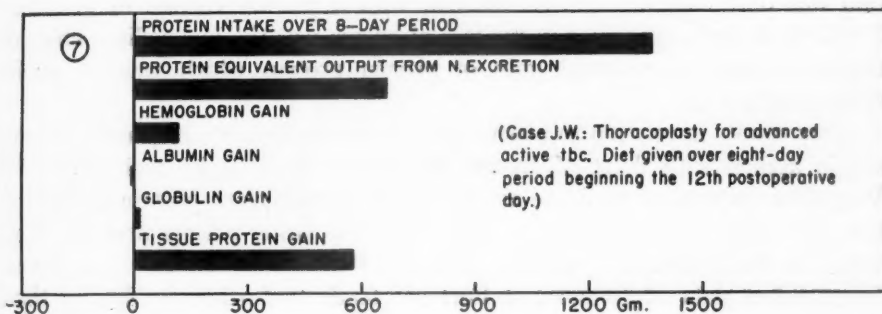


CHART 7.—Case J. W.: Nitrogen Balance Chart.

The patient suffered from advanced active tuberculosis for which a thoracoplasty was performed. The diet was given over an eight-day period starting on the 12th postoperative day.

Plasma albumin and globulin regeneration was variable although it also tended to be suppressed. Some cases, however, manifested accelerated plasma globulin formation in the presence of infection. This is illustrated by the studies of Case J. H. (Chart 4) and Case J. W. (Chart 7) as shown in the accompanying charts and Table I. The first patient was followed five days before gross wound infection occurred, and five days during infection. In the absence of infection, blood regeneration was similar to that manifested by the other uncomplicated cases. During infection, hemoglobin and plasma albumin loss occurred,

whereas the total circulating plasma globulin increased. Another Case, that of B. A. (Chart 8), presented gross infection from the beginning, and during a seven-day study period lost one-third of her total circulating hemoglobin. Both plasma albumin and globulin revealed increases and nitrogen retention was excellent. This patient was quite edematous at the start of the feeding period. Her plasma protein concentration at this time was 5.96 Gm. per 100 cc. plasma, with a plasma volume of 3,569 cc.; at the end of a seven-day period,

CHART 8

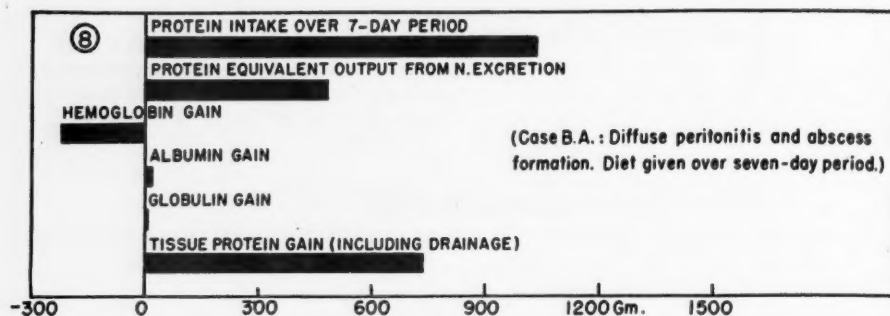


CHART 8.—Case B. A.: Nitrogen Balance Chart.

Diffuse peritonitis with abscess formation. The diet was given over a seven-day period.

most of the clinical edema had disappeared and her plasma protein concentration was 6.97 Gm. per 100 cc. plasma, with a plasma volume of 3,292 cc. Probably the greatest factor in the loss of edema was the low sodium chloride regimen rather than actual gain of plasma protein which was in reality quite small.

Our results in relation to plasma protein concentration and plasma volume are in accord with those of Lyons, Madden and Whipple, and others.¹³⁻¹⁶ Very little correlation could be established between plasma protein concentrations and plasma volume, and, in turn, total circulating plasma protein. Both values tended to show the same directional shift but much variation is apparent. Unpublished data of Evans and Forbes¹⁷ tends to further emphasize these findings.

SUMMARY

It is believed that a high protein, high caloric, high vitamin diet in liquid form is feasible to administer to selected postoperative patients. The type of diet in this study has been well utilized and probably could be employed to advantage in some cases where more expensive modes of nitrogen intake are contemplated.

A method has been presented which facilitates nitrogen balance studies by the use of a uniform, liquid diet whose protein intake is easily determined.

Positive nitrogen balance was established in all patients studied. Protein regeneration tended to be more marked in those tissues where competition was greatest for the available amino acids.

PROTEIN DIET IN SURGICAL PATIENTS

In the presence of infection, hemoglobin regeneration did not equal its destruction. Plasma albumin and globulin formation were variable.

Plasma protein concentration and hemoglobin determinations *per se* do not reflect plasma protein and hemoglobin regeneration.

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BRIEF COMMUNICATIONS

GASTROJEJUNOCOLIC FISTULA FOLLOWING GASTRECTOMY

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THIS DISCUSSION was prompted by the recent consideration of a patient, who had a gastrojejunal fistula, following gastrectomy. The patient was in very poor condition, and had a concomitant acute intestinal obstruction, which made necessary some sort of modified procedure in regard to the fistula. In the past it has been our practice to resect the involved portion of the jejunum, large bowel and stomach, repair the bowel and jejunum, and reform the gastrojejunal anastomosis.

We were familiar with the side-tracking, two-stage procedure, of Lahey and Marshall, and of Pfeiffer and Kent's stage procedure, using a proximal colostomy as the first stage. With the number of previous celiotomies had by this patient, a stage procedure was difficult to contemplate. Therefore, the following plan was visualized, and turned out to be practicable:

The adhesive band causing the intestinal obstruction was first freed. The colon was disconnected from the gastrojejunal anastomosis and its opening closed by two layers of catgut sutures overlaid by one layer of interrupted figure-of-8 cotton No. 40 sutures. The ulcer and gastrojejunal anastomosis was thus opened in part, and no more than necessary. The edges of the fistulous tract were excised and the anastomosis repaired, having interfered with less than one-third of the circumference of the anastomosis in the dissection. The time elapsed was short and the trauma slight. An uneventful convalescence supervened, and rapid weight-gain occurred.

Case Report.—Case No. 8598: E. C., a 32-year-old, white male, entered St. Vincent's Hospital, September 13, 1945, with the complaint of vomiting and abdominal pain. For the last nine months, the patient has had attacks of abdominal pain with periodic attacks of vomiting of foul liquid, gray-colored material, and of bowel movements of the same character.

In 1935, the patient had a perforation of a peptic ulcer, without previous history or warning. The perforation was closed at that time.

In 1937, the patient had an acute mechanical intestinal obstruction, caused by adhesions; and six feet of terminal ileum had to be resected, because of strangulation.

In 1942, the patient again had a perforation without any previous symptoms; and after closure of the ulcer had persistent ulcer symptoms. Several months later, he had a subtotal gastrectomy, posterior Hoffmeister-Finsterer type. The patient was quite well then, until in March, 1945, at which time he began to have abdominal pain, gray-colored vomitus and stool; and on upper gastro-intestinal roentgenologic examination and gallbladder dye test, gallstones were found, and no gastrojejunal fistula demonstrated. The gallbladder and stones were removed, in May, 1945, and following this, the patient developed two mechanical intestinal obstructions, both of which were operated upon and, in the second instance, a Miller-Abbott tube was threaded clear down to the colon. This was left in place for 12 days. The patient gained some weight but still continued to have periodic attacks of some type of vomiting and, on re-



FIG. 1.—Roentgenogram of the gastrojejunocolic fistula. Barium from stomach immediately entered the colon as well as the jejunum.

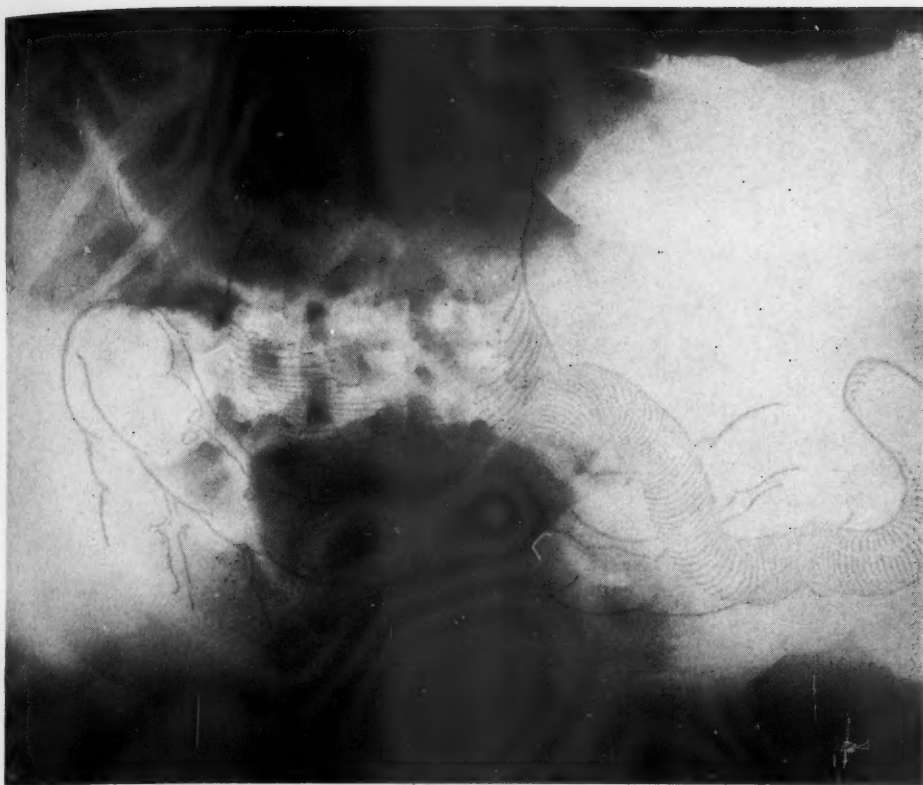


FIG. 2.—Roentgenogram showing superimposed acute intestinal obstruction while patient was awaiting surgery for the fistula.

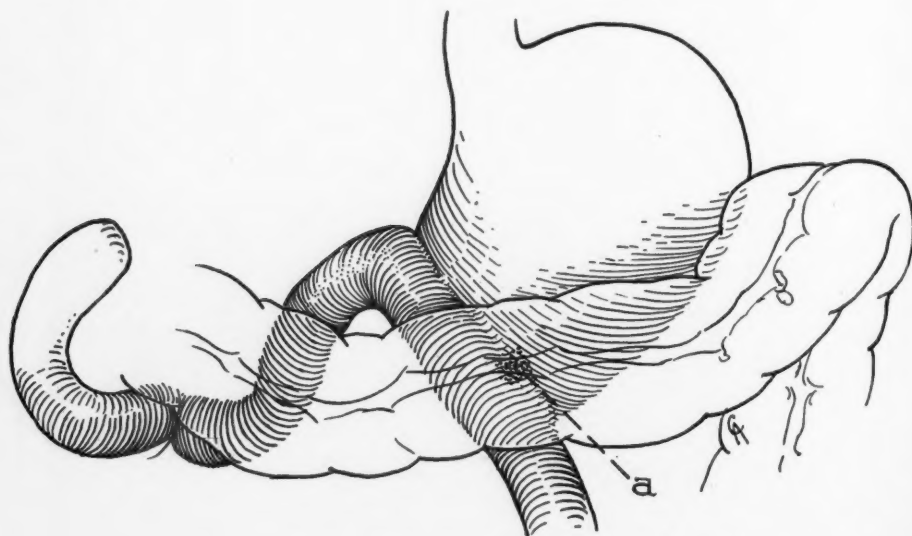


FIG. 3.—Site (a) of gastrojejunocolic fistula.

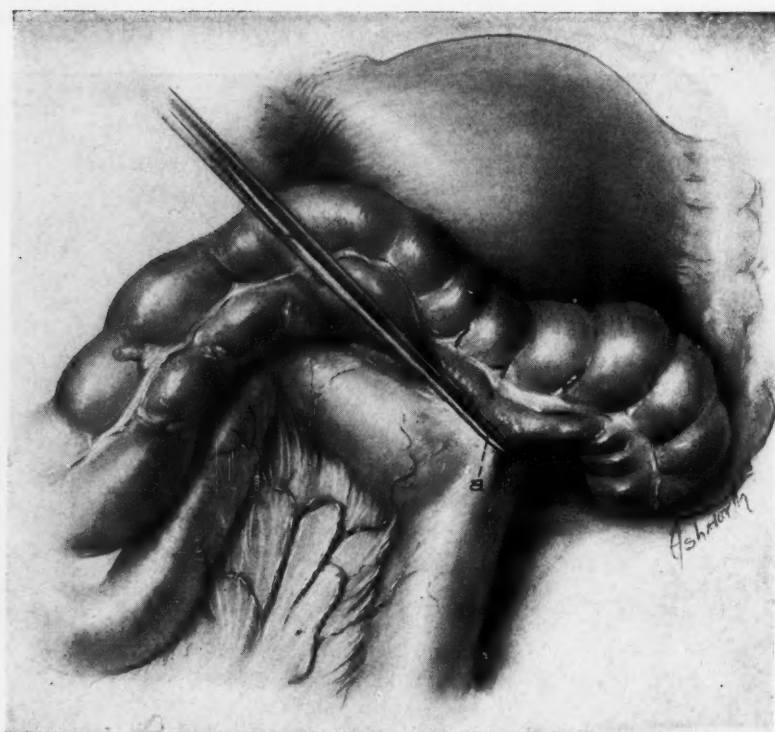


FIG. 4.—Colon being disconnected (a) from fistula.

GASTROJEJUNOCOLIC FISTULA

examination, the upper gastro-intestinal and barium enema, a gastrojejunocolic fistula was this time demonstrated. While the patient was awaiting surgery, another acute mechanical intestinal obstruction developed. Operation was performed for relief of the obstruction and relief of the gastrojejunocolic fistula.

SUMMARY

(1) A plan is suggested for very bad-risk cases of gastrojejunocolic fistula, following gastrectomy, in which the colon is separated and repaired and, instead of a complete new gastrectomy, the existing anastomosis is interfered with as little as possible, and then repaired.

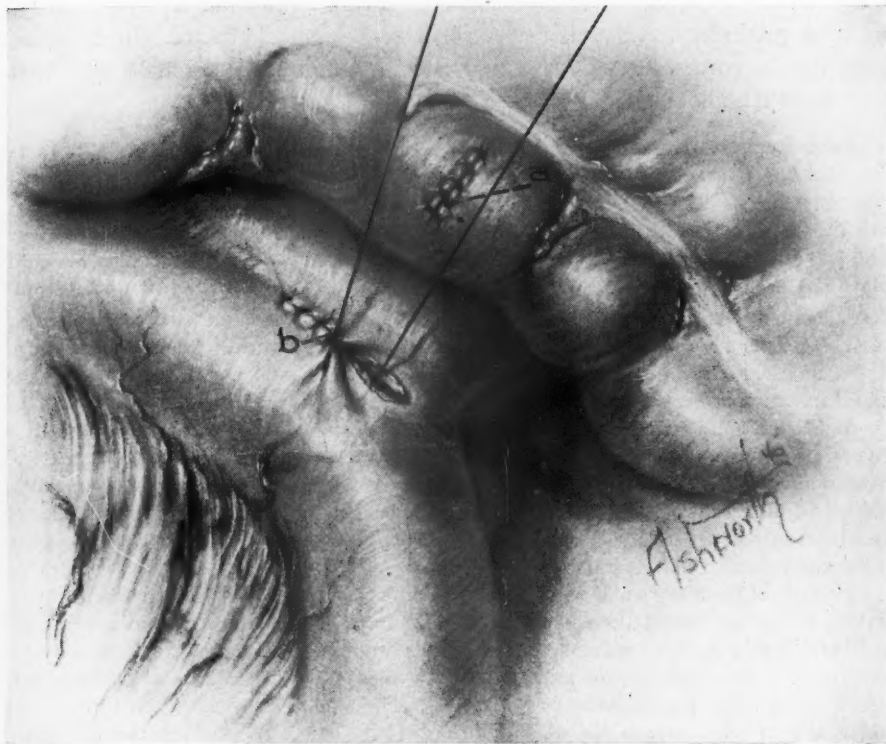


FIG. 5.—Colon closed (a) transversely.
Gastrojejunal anastomosis (b) being repaired.

(2) The same principle might be applied to such a fistula arising after gastro-enterostomy, even though a later gastrectomy might be contemplated in either of the two cases.

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ACUTE INTESTINAL OBSTRUCTION CAUSED BY CLAMPING OF THE INTESTINE IN THE UMBILICAL CORD CLAMP

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THE CASE, that we are presenting, is that of a newborn infant, who had an accidental Mikulicz' procedure performed upon the small bowel by the placing of the umbilical cord clamp. The case is reported because of its great rarity, and as a reminder to all that such an accident may take place. In tying or clamping the cord, especially one that is unduly large, it should be tied well away from the abdomen.

Case Report.—Nos. 147752 and 95862; Doernbecher Hospital: The child, a four-day-old white female, entered Doernbecher Hospital, September 7, 1945. It was a full term, spontaneous delivery, birth weight 7 lbs. 13¾ oz. The child was admitted vomiting, with the history of bleeding and intestinal contents coming from the umbilical cord. The child was born with a very large cord, approximately 1.5 inches in diameter and the cord clamp was used. The day before admission, September 6, 1945, the child began to vomit. This consisted of a green bile-stained material. The morning of admission some bleeding was noted from the umbilicus, so the clamp was placed closer to the abdomen. At 4:30 P. M. more bleeding occurred, and this was attempted to be controlled by the local physician. At that time bowel content was seen to come from the wound.

When the child was admitted to Doernbecher Hospital it was extremely ill, with a temperature of 104.6 F., pulse 160, respiration 32. Physical examination revealed an apical systolic murmur in the heart; a distended abdomen, and an incision across the umbilicus which had been sutured, a small stump protruding below the incision. The plain film of the abdomen showed some distension of the small bowel (Fig. 1); and a roentgenogram of the chest showed the heart on the right side of the body.

Because of the history and physical findings, the child was taken to the surgery immediately, and it was found, after dissection of the sutured stump, that a loop of small bowel had been caught in the cord and the blind ends were necrotic and were leaking bowel content. The proximal loop of small intestine was very dilated, the distal end was collapsed, being about the thickness of a cigarette. The stumps were closed in three layers and a side-to-side anastomosis was performed (Fig. 2). The primary closure of the abdomen was then done.

The postoperative course was exceedingly stormy. Considerable distension of the abdomen was present, with vomiting and fever. The child was given blood transfusions, oxygen, penicillin and continuous gastric suction. About the 8th postoperative day suction was able to be discontinued, and the child continued to progress favorably until discharge on October 10, 1945. Further studies of the heart revealed a congenital lesion, in addition to the malrotation of the heart. At discharge, October 10, 1945, the child was eating very well, having normal bowel movements and having no difficulty as far as the abdominal wound or the heart were concerned.

This case may be considered to fall into the rather rare condition of hernia into the umbilical cord, or omphalocele, as it is perhaps better termed, in order to separate it from the ordinary types of umbilical hernia.

From the sixth to the tenth week in the embryo, the base of the umbilical cord contains loops of intestines. After the tenth week, the intestines nor-

INTESTINAL OBSTRUCTION IN NEWBORN



FIG. 1.—Roentgenogram showing dilated small bowel following the accidental injury of the bowel by the umbilical cord clamp.

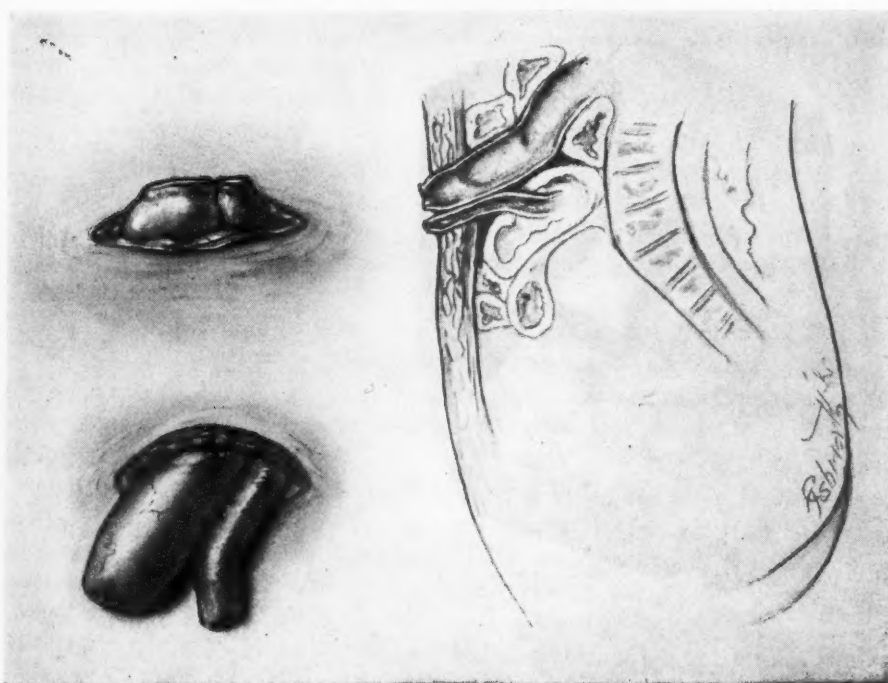


FIG. 2.—(Upper left) : The appearance of the bowel after it had been injured.
(Right) : Sagittal section showing same.
(Lower left) : Beginning of the lateral anastomosis after closure of both ends of the divided bowel.

mally recede into the abdomen; if they do not, an omphalocele results. Such umbilical eventrations may be very small or quite large. In such cases, the abdominal viscera are covered by a very thin covering, which rapidly dries and becomes necrotic. Thus, repair of such defects must be undertaken in the first few hours of life. This, of course, differs from the surgical treatment of the ordinary umbilical hernia, which is not operated upon prior to the age of one year, unless the defect is very great or unless evidence of incarceration is noted. The ordinary umbilical hernia is caused by a weakness of the rectus fascia with diastasis of the recti muscles, and, of course, is covered by skin and not by the thin parchment-like membrane of the cord.

SUMMARY

(1) The successful outcome following the lateral anastomosis of the injured small bowel is ascribed to the diligent care of a very capable House staff of doctors and nurses, whose ability to give a newborn infant daily transfusions and intravenous solutions over the critical period spelled the difference between life and death.

(2) The probable reason that this bowel was injured is that a small congenital hernia into the umbilical cord, or omphalocele, was present.

(3) All cords, especially unusual looking ones, should be clamped well away from the body.

(4) Herniae into the umbilical cord, or omphalocele, should be repaired immediately after birth.

A TRANSFASCIAL INCISION AS AN APPROACH TO THE KIDNEY AND RETROPERITONEAL SPACE

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A PROPER INCISION is one that adheres to physiologico-anatomic principles and procures a good operative field with the least amount of tissue damage and time wasted. Although no claim of originality is made for the above incision, I have not seen it described in the literature.

All incisions used as an approach to retroperitoneal surgery, including the 12th-rib incision, recently described by Digby, of China, and better known as the "Clairmont method," tend to sever important tissues and are too close to pleura and peritoneum, to be trouble-free for the general surgeon.

During the last seven years, I have employed the transfascial incision in operations upon the sympathetic and urinary systems, and because of its simplicity and safety, feel it worth while reporting. The incision is wholly through fascial tissue, without muscle-cutting or -splitting, roomy, free from danger of entering pleura or peritoneum, easy of closure, and without danger of herniation. It is also shockless and time-saving. A brief anatomic description and technic follows:

Anatomy.—The lumbodorsal fascia (Fig. 1) is in two layers, anterior and posterior, forming a sheath for the sacrospinalis muscle. The anterior layer, in turn, unites with the aponeurosis on the quadratus lumborum muscle to form a sheath for the latter muscle, both sheaths fusing lateral to these muscles to form a common tendon, or origin for the transversus abdominis muscle.

The transversalis fascia, which is scanty in this region, unites with the subperitoneal fascia and the aponeurosis of the quadratus lumborum and psoas to form the prerenal fascia which, in turn, encloses the kidney and its fatty capsule. Behind the renal fascia there is considerable fat, constituting the paranephric body.

The subcostal, ilio-inguinal, and hypogastric nerves transverse between quadratus lumborum and its fascia to their respective distribution.

The lumbar vessels arising from the aorta, cross behind the quadratus lumborum muscle to enter the space between the transversus abdominis and obliquus internus to their respective distribution.

The kidneys, suspended through the renal fascia and apposition of neighboring viscera, lie with their upper poles on a level with the upper border of the 12th thoracic vertebra, the lower poles on a level with the 3rd lumbar vertebra; the posterior surfaces being largely on the quadratus lumborum muscles.

The order of structure, therefore, from skin surface to kidney (Fig. 1), are skin, superficial fascia, posterior layer of lumbodorsal fascia, sacrospinalis muscle, anterior layer of lumbodorsal fascia, lumbar vessels and nerves, (sub-

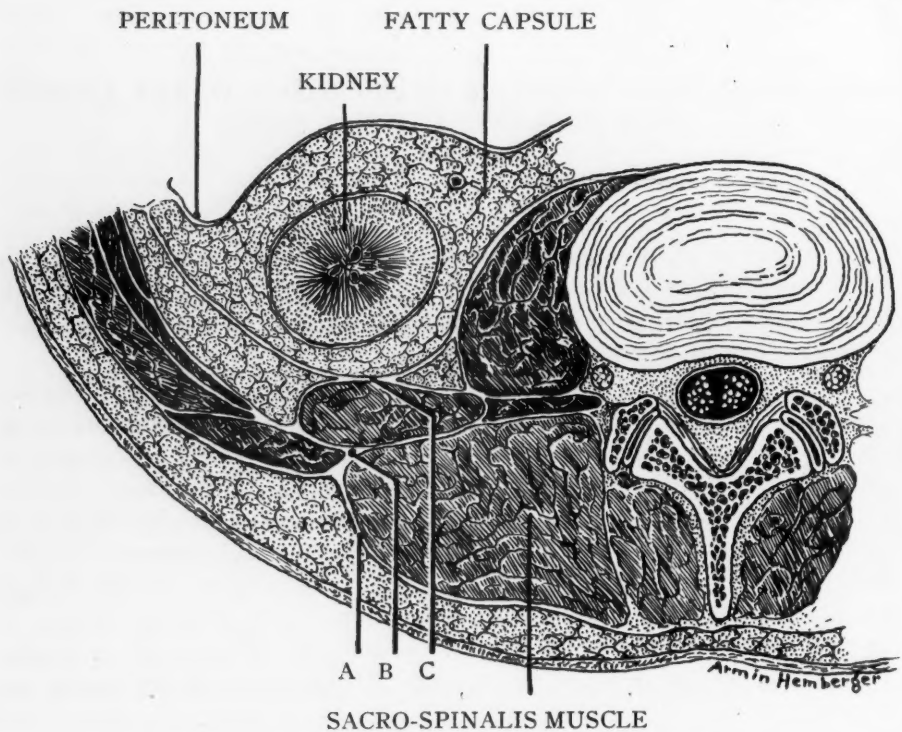
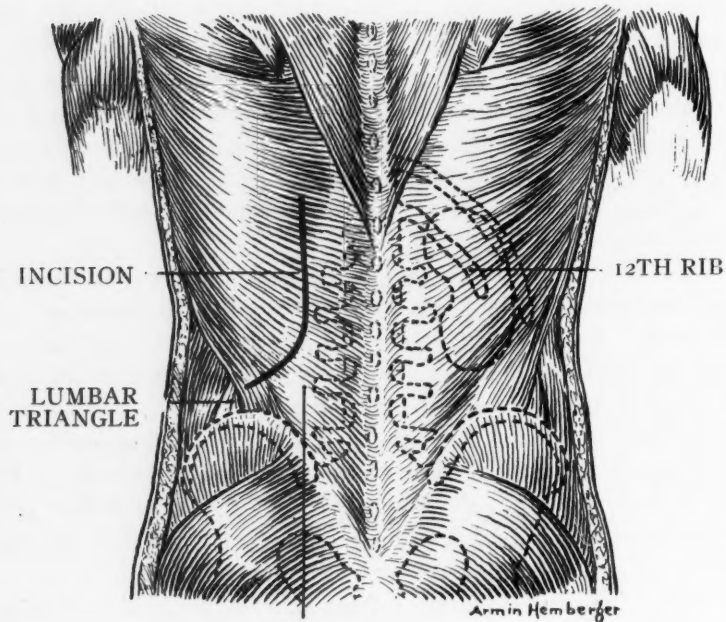


FIG. 1.—Showing structure of the lumbodorsal fascia.



LUMBO-DORASAL FASCIA

FIG. 2.—Illustrating operative technic.

A SAFE LUMBAR INCISION

costal, ilio-inguinal, and hypogastric), transversalis fascia, (fusion of transversalis subperitoneal and aponeurosis of quadratus lumborum) and kidney.

Technic.—General, spinal-paravertebral or local anesthesia may be employed. The usual kidney position, with moderate Fowler's, is most satisfactory. A vertical incision with a lower horizontal limb is used, extending from the 12th rib to crest of ileum at outer edge of sacrospinalis muscle and parallel with the vertebral column (Fig. 2). If more room is required, the 12th rib may be cut transversally and subperiostially, or the horizontal limb may be prolonged, without danger of injuring pleura or peritoneum. These prolongations are rarely necessary, having been used on one occasion only, due to a marked scoliosis present.

Incise skin, superficial fascia, and posterior sheath of sacrospinalis; retract the latter muscle and incise anterior sheath to quadratus lumborum, retract this muscle, and incise its anterior sheath, which forms a part of the transversalis fascia with the subperitoneal fascia, and the kidney with its fatty capsule, presents itself anterior to operative field (Fig. 1 a, b, c).

Minor vessels and nerves can be ignored, avoiding the subcostals, ilio-inguinal, hypogastric and the deep iliac circumflex from above downward, respectively.

There is no muscle-cutting or -splitting, no danger of entering peritoneum or pleura nor injuring any important structures, and postoperative hernia has never occurred. All the retroperitoneal tissues are within the surgeon's reach and can be dealt with, without difficulty. Better control of the pedicle, pelvis, and ureter can be had with this incision than any other used at present. The time-element is greatly reduced, and the incision is simple of performance and closure. Palpation of the opposite kidney has been possible in obscure cases.

The writer has used the described incision, obtaining free exposure and success for the removal of large kidneys, such as hypernephromas, sarcomas, hydropyonephrosis, and kidney and ureter stones. The same incision has also been used by the writer for operations upon the sympathetic system, such as splanchnicectomy, celiac ganglionectomy, lumbar ganglio- and ramisectomy.

SUMMARY

A simple incision is described which fulfils all the physiologico-anatomic principles.

The illustrations are taken from Gray's Anatomy.

GANGLION OF THE COMMON PERONEAL NERVE

CASE REPORT

LT. COL. RICHARD WARREN, M.C., A.U.S.

GANGLION in the neighborhood of the knee joint is not uncommon. There are few surgeons who have not resected a cystic structure adherent to the muscles, tendon, or ligaments around the knee and have found that it is difficult to remove without spilling its clear, jelly-like contents and leaving behind some of its poorly defined posterior wall. Ganglion of a peripheral nerve, however, is so rare¹ that it appears fitting to record a recently encountered case in which the common peroneal nerve was involved and had to be resected.

Insofar as can be determined there are five previously recorded cases of ganglion of a peripheral nerve. In 1901, Hartwell² recorded a case in which the median nerve was involved. Loeffler and Volkmann,³ in 1920, reported a ganglion of the tibial nerve, 1 x 2 cm. in size, which produced pain and paresthesia, causing a mistaken diagnosis of foot strain in a 36-year-old railroad worker. In 1922, Sultan⁴ recorded a ganglion, 2 x 3 cm., causing pain and complete paralysis of the deep peroneal nerve in a 56-year-old male. The pain, but not the paralysis, was relieved by dissection of the ganglion from the nerve. Dubs,⁵ in 1922, found a small ganglion of the dorsal branch of the ulnar nerve in a 68-year-old man. In 1937, Ferguson⁶ reported a case in a 15-year-old boy, in whom the ganglion, 6 x 3 cm. in size, arose from the sheath of the peroneal nerve and, fortunately, could be dissected from it.

Case Report.—A 29-year-old male, sports director in the American Red Cross, entered the hospital complaining of the appearance, six weeks previously, of a lump below and lateral to the left knee followed, three weeks later, by a numbness of the lower leg and a drop foot. There had been no antecedent trauma or other precipitating factor.

Examination showed a rubbery, spindle-shaped mass lying over the head of the left fibula following the course of the common and deep peroneal nerves. There was no tenderness. There was complete paralysis of the common peroneal nerve with drop foot, reaction of degeneration in the anterior tibial and peroneal muscle group, and a typical loss of sensation in the distribution of the common peroneal nerve.

Operation, three days after admission, performed under gas-oxygen-ether anesthesia, revealed a multilocular mass, 6.5 x 3.5 x 3.0 cm., containing clear jelly-like material characteristic of a ganglion. Incorporated in the wall of the ganglion, over a band 2 cm. in width, ran the common peroneal nerve. Small locules of cyst were lying at many points among the nerve fibers which seemed edematous and abnormal. In view of the already complete paralysis, the total involvement of the nerve by the cyst, and the appearance of the fibers, a complete resection of the ganglion and involved nerve was performed. At the lowermost end of the ganglion a small pedicle of the cyst left the nerve trunk and was attached to the tibiofibular ligament just below the knee joint.

GANGLION OF COMMON PERONEAL NERVE

The patient's postoperative course was uneventful. He was able to walk about normally, with an appliance to correct the drop foot. He was referred to another hospital for the consideration of the possibility of a nerve graft. Because of retraction of nerve ends the gap in the nerve amounted to about 7 cm., and little hope was held out for success of this procedure.

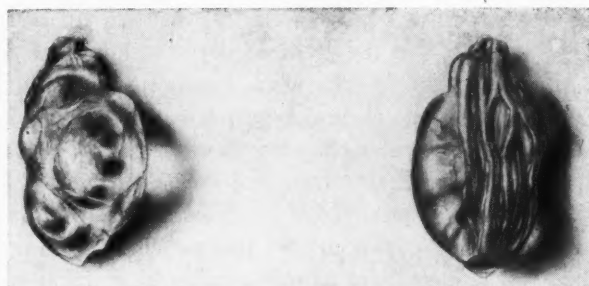


FIG. 1.—Gross appearance of the ganglion. It is here depicted as slightly less than half its actual size ($6.5 \times 3.5 \times 3.0$ cm.).

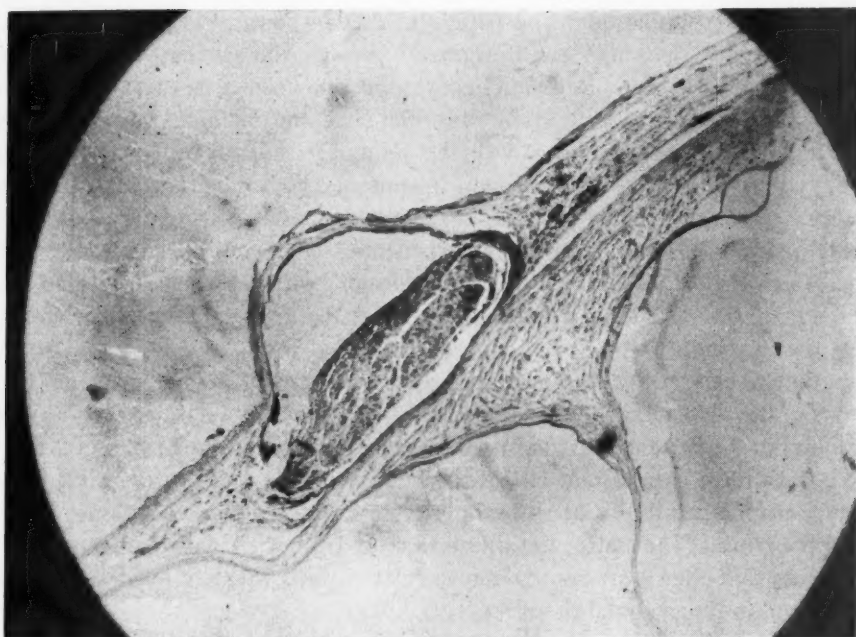


FIG. 2.—Low power photomicrograph of the wall of the ganglion.

Pathologic Examination.—"The specimen shows the wall of a cystic structure formed of connective tissue, without specific lining cells. The lining and wall are formed of collagenous connective tissue. There are patches of loosely arranged myxomatous tissue. Nerves course both through and over the cyst wall, and myxomatous zones are present in epineurium and perineurium. The smaller cystic structure is

formed of collagenous connective tissue including a cyst similar to the above which contains granular coagulum. Two nerve fasciculi are present in the immediately adjoining tissue. One luminated structure is partly lined by fibrous synovial membrane."

DISCUSSION.—From the descriptions of the cases of Hartwell, Loeffler and Volkmann, Sultan and Dubs, and the detailed description of Ferguson's case, the patient, here recorded, appears similar to them in all respects but one. In none of the other cases had the involved nerve to be resected. In only one case, however, that of Sultan, had the nerve function been totally destroyed by the ganglion. He produced no clinical improvement by excision. In the other four cases in which the clinical signs were those of partial nerve involvement, immediate improvement or disappearance of the neurologic signs resulted.

In none of the reports is recurrence mentioned, but those cases, just as this one, were not followed for long enough, so that conclusion can not be drawn on this point. The great tendency for ganglia arising in or from the bursae, ligaments or tendons about the knee joint to recur is mentioned often in the literature and has been observed in the clinical experience of the writer. A recurrence as late as 18 years after the original excision has been recently seen.

The etiology and pathologic characteristics of ganglion have been the subject of much speculation. The papers of Ledderhose,⁷ Floderus,⁸ Carp and Stout,⁹ King,¹⁰ Jensen,¹² and Ferguson⁶ present the various theories as to etiology that have been offered. There is a general consensus that these ganglia about the knee joint, which are multilocular, contain mucinous jelly-like material and do not communicate with the joint, are entirely different from the synovial cysts (Baker's cysts) which contain clear fluid and usually communicate with the knee joint. The latter may be herniations of synovia but are more probably distentions of the gastrocnemio-semimembranosus bursa (Wilson, Eyre-Brook and Francis¹³). The former, with which we are here concerned, are the product of a reaction, degeneration or metaplasia of the connective tissue around a joint. Ledderhose, Carp and Stout, and Ferguson believe that they are the result of a mucinous degeneration of connective tissue. King holds to the theory that the spindle cells of the connective tissue around a joint respond to the stimulus of trauma or friction, undergo metaplasia, secrete mucin and, thus, form pseudojoint cavities—which is what ganglia really are. Jensen brings up the possibility of embryonic rests of ectopic synovial tissue. Wherever the truth of the matter lies, it seems clear from their nature and proximity to joints that they bear some definite relationship, whether by descent or by imitation, to the synovial tissue.

The question as to whether the ganglia which involve peripheral nerves arise in the connective tissue of the epi- or perineurium or whether they arise in neighboring structures and invade the nerve is also to be settled. Carp and Stout believe the latter to be the case. In the case recorded there was a stalk or pedicle leading from the tibiofibular ligament, suggesting that mechanism here. We must conclude that any of the connective tissue elements around a joint, including the perineurium, may be the origin of ganglion which occurs as the result of some unknown stimulus.

SUMMARY

1. A case of ganglion of a peripheral nerve is reported.
2. A review of the literature with a summary of the theories as to the etiology of the condition is presented.

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STUDIES ON THE INGUINAL REGION

II. THE ANATOMY OF THE INGUINAL (HESSELBACH) TRIANGLE

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ALTHOUGH the inguinal (Hesselbach) triangle is the location of some five per cent of all herniae encountered, nevertheless, a protrusion here can be as disabling as one in any location. It would seem that an area so frequently dissected in the laboratory and observed so often by surgeons would be thoroughly understood and agreed upon by all workers. There is disagreement as to the precise location of a direct (diverticular) hernia as well as its relation to the ventral abdominal wall. Two types of hernia occur in the inguinal triangle. The most important one is the diverticular variety which closely simulates the direct form except in point of origin and relation to the spermatic cord. The second form is a general bulging of the whole triangle and sometimes of the whole lower abdominal wall. Andrews¹ (1934) refers to this type as the despair of the surgeon. This type has not been encountered and will not be considered in this study.

Our objective has been to correlate the fundamental anatomy of the inguinal triangle and to indicate the relationships of a direct (diverticular) hernia to the layering of the ventral abdominal wall.

MATERIALS AND METHODS

During the past ten years a record has been made of 12 direct (diverticular) herniae encountered in the gross anatomy laboratory at West Virginia and the University of Pittsburgh Medical Schools. These observations have been supplemented by a study of the parietal layers of the ventral abdominal wall in specimens where no hernia existed. A total of 268 body-halves have been considered. All direct herniae were in males except one. This form of hernia is extremely rare in the female. The one encountered did not differ from those present in males.

1. *The Peritoneum.*—There are at least three structures that may produce prominent folds of the peritoneum. These are the urachus, the obliterated hypogastric arteries and the deep inferior epigastric arteries. In some specimens the folds are very shallow and in others quite deep. Plicae as tall as 4.1 cm. have been observed. They are more frequently associated with the obliterated umbilical arteries than with the urachus or the deep inferior epigastric arteries. They are sometimes bilateral but may be present on one side only (Fig. 1).

2. *The Transversus Fascia.*—This name has been chosen in preference to the generally used term "transversalis fascia." The term transversus is appropriate, because it refers to a true deep fascia and because it is associated with the transversus muscle, Anson² (1938). Any muscle or aponeurosis has

an areolar tissue on each aspect. This areolar tissue does not represent a deep fascia, in the sense that this term is generally employed, Grant⁵ (1944). If it were not for the loose areolar tissue surrounding structures they would not be able to glide over each other during movement. In the instance under consideration the transversus fascia is a direct continuation of the dorsal layer of the rectus sheath. When the peritoneum is carefully removed from the lower ventral abdominal wall, there is left the dorsal portion of the rectus sheath. This dorsal portion of the rectus sheath can be separated from the rectus muscle and below the level of the linea semicircularis continues as the true transversus fascia. It attaches along the line of origin of the transversus muscle but is directly continuous with the iliac fascia. This establishes it as a true deep fascia. The degree of development is in proportion to the muscular development of the individual. In sparse individuals it may be thin and close to the peritoneum, but in stout ones considerable preperitoneal tissue may intervene.

3. The Conjoined Aponeurosis.—

The internal oblique and transversus muscles unite to make the conjoined aponeurosis. Careful consideration has been given to the medial and inferior extent of these two muscles and their aponeuroses. In general, the muscle portion of the internal oblique extends further medially than that of the transversus. In the 268 body-halves examined the internal oblique was muscular in the whole of the inguinal triangle in 20% of all specimens, furnished no muscle in 31.7%, and in 48.3% the muscle portion made up one-half or more of the inguinal triangle. In the same specimens the transversus furnished no muscle tissue in the triangle in slightly over 54.6% of the body-halves, covered the whole inguinal triangle in less than 4.1% and made up one-half of the triangle in 41.3%.

The inferior extent of these muscles is also important. The internal oblique arises from the whole of the inguinal ligament down to the spermatic cord. Chandler and Schadewald⁴ (1944), Anson (1938). In contrast the transversus arose from the whole of the inguinal ligament in 5% of the 268 body-halves. Anson (1938) reported an incidence of 3% in 200 body-halves. Even



FIG. 1.—Photograph of the internal surface of a left half of the ventral abdominal wall, showing a fossa 4.1 cm. deep made by the obliterated hypogastric artery. (a) The peritoneal fossa; (b) obliterated hypogastric artery; (c) rectus abdominis muscle; (d) urinary bladder.

when the transversus does not arise from the whole of the inguinal ligament it may be represented by a fascial or aponeurotic layer (Figs. 2 and 3).

4. *The Aponeurosis of the External Oblique.*—This layer most nearly fits the usual description found in most textbooks. The size of the internal abdominal ring varies considerably. When large the oblique fibers associated with the ring may also be separated somewhat. A reflected inguinal ligament—a portion extending upward and medially—was rarely observed. Thinned-

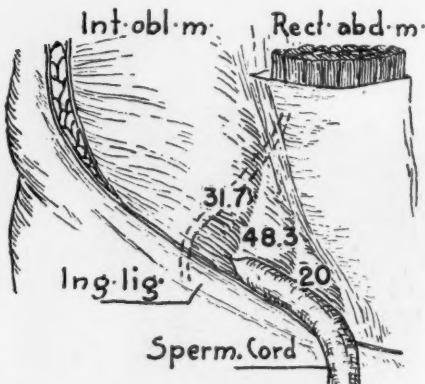


FIG. 2

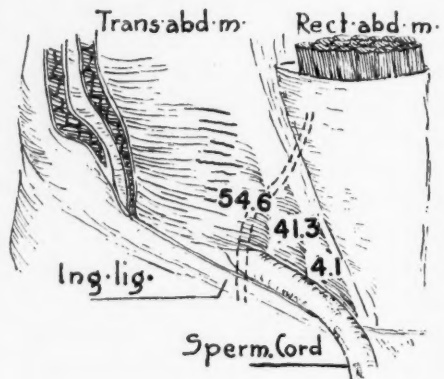


FIG. 3

FIG. 2.—The medial extent of the internal oblique as muscle into the inguinal (Hesselbach) triangle. In 20% of 268 body-halves this muscle extends through the whole of the triangle and in some instances overlapped the rectus. About one-half of the triangle was muscular in 48.3% and only slightly, or not at all, in 31.7%. Deep inferior epigastric artery is shown by dotted lines.

FIG. 3.—The medial extent of the transversus abdominis as muscle into the inguinal (Hesselbach) triangle. In 4.1% of 268 body-halves this muscle extended through the whole triangle, and occasionally overlapped the rectus. About one-half of the triangle was muscular in 41.3% and only slightly, or not at all, in 54.6%. Deep inferior epigastric artery is shown by dotted lines.

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out or fascial areas may be present occasionally. This layer does not unite with the rectus sheath until near the midline, as described and illustrated by Anson and McVay (1938).

DISCUSSION.—What are the elements of weakness which precede the formation of a direct hernia? The presence of fossae on either side of the obliterated hypogastric arteries are thought to concentrate intra-abdominal pressure in a restricted area. If the peritoneum is stretched over such a region a protrusion is gradually formed when the fossae extend inferior to the inguinal ligament the protrusion may be into the femoral canal.

These fossae in the peritoneal layer may permit the beginning of a protrusion but if it is to become extensive at all it must find weak areas in other layers also, especially the conjoined aponeurosis.

Direct herniae have been encountered in the absence of peritoneal fossae. Probably the most important single factor in the strength or weakness of the

ventral abdominal wall is the condition of the conjoined aponeurosis in the inguinal triangle. If either the internal oblique or the transversus are muscular in the triangle protrusions may take place since muscle fasciculi are often held together only slightly by fibrous tissue. Hernial protrusions have also been found in the aponeurotic portion of the triangle. By subjecting each layer of the ventral abdominal wall to a bright light thinned-out fascial areas are sometimes noted. It is assumed that these thinned-out regions are the ones where direct herniae occur. In one specimen bilateral herniae were present. On one side the protrusion was just superior to the inguinal ligament and in the suprapubic fossa. The sac, about the size of a lead pencil, did not contain any viscus. The protrusion extended through the external inguinal ring and down the spermatic cord a short distance. On the opposite side the hernia arose in the medial inguinal fossa. Observers are about equally divided as to the most common fossa of origin; some report that direct hernia is almost always found in the suprapubic fossa and about an equal number state that it usually arises in the medial inguinal fossa. Of the 12 direct herniae observed in this series seven were in the suprapubic and five in the medial inguinal fossa. This number is far too small to be significant but it may indicate that protrusions are about as likely to occur in one as the other fossa. There is probably but little difference to the surgeon which fossa gives origin to the protrusion.

The aponeurosis of the external oblique is somewhat less important than fossae in the peritoneum or thinned-out areas in the conjoined aponeurosis. If weak areas or a dilated external ring exist, these contribute to the general weakness of the wall. Neither of these conditions predispose to a direct hernia. The primary fundamental weakness is the presence of peritoneal fossae and weak thinned-out areas in the conjoined aponeurosis. The result of a protrusion through the external inguinal ring is dilation of the ring and enlargement of the fascial coverings of the spermatic cord.

SUMMARY

Observations on 12 direct (diverticular) herniae and a study of the parietal layers of the ventral abdominal wall in the inguinal (Hesselbach) triangle in 268 body-halves show that:

1. Seven of the direct herniae were in the suprapubic fossa and five in the middle inguinal fossa.
2. The possible influence of fossae associated with the urachus and obliterated umbilical arteries is discussed.
3. Direct herniae have been noted in the muscular and in the aponeurotic portions of the inguinal triangle. The rôle of weak fascial areas in the layering of the inguinal triangle is presented.
4. The course of a direct diverticular inguinal hernia is usually through the external abdominal ring. An enlarged external inguinal ring probably does not predispose to hernia unless there is associated with it a weakness of the other parietal layers.

5. The strength of the inguinal triangle depends mainly on the presence or absence of fossae in the peritoneum and the condition of the conjoined aponeurosis—is it muscular, aponeurotic, or fascial?

6. There is a definite need for autopsy, surgical and dissecting room reports on the association of direct herniae with peritoneal fossae.

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